



3-1975

A Petrographic and Spectrographic Analysis of Several Soapstone Artifacts from Tennessee and Soapstone Deposits in North Carolina and South Carolina: in an Attempt to Determine the Source Area of the Artifacts

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To the Graduate Council:

I am submitting herewith a thesis written by Earl Roger Bohanan entitled "A Petrographic and Spectrographic Analysis of Several Soapstone Artifacts from Tennessee and Soapstone Deposits in North Carolina and South Carolina: in an Attempt to Determine the Source Area of the Artifacts." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geology.

Otto C. Kopp, Major Professor

We have read this thesis and recommend its acceptance:

L.T. Larson, Harry J. Klepser

Accepted for the Council:

Carolyn R. Hodges

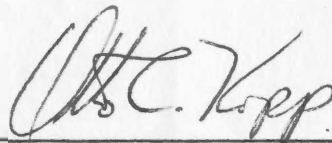
Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

December 22, 1974


To the Graduate Council:

I am submitting herewith a thesis written by Earl Roger Bohanan, Jr., entitled "A Petrographic and Spectrographic Analysis of Several Soapstone Artifacts from Tennessee and Soapstone Deposits in North Carolina and South Carolina in an Attempt to Determine the Source Area of the Artifacts." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geology.

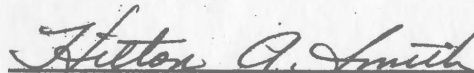


Otto C. Kopp, Major Professor

We have read this thesis
and recommend its acceptance:



Accepted for the Council:



Vice Chancellor
Graduate Studies and Research

A PETROGRAPHIC AND SPECTROGRAPHIC ANALYSIS OF SEVERAL SOAPSTONE
ARTIFACTS FROM TENNESSEE AND SOAPSTONE DEPOSITS IN NORTH
CAROLINA AND SOUTH CAROLINA IN AN ATTEMPT TO
DETERMINE THE SOURCE AREA OF THE ARTIFACTS

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee

Earl Roger Bohanan, Jr.

March 1975

ACKNOWLEDGEMENTS

I am grateful to Dr. O. C. Kopp for his guidance and assistance in every aspect of this study. I am also grateful to Dr. L. T. Larson for his assistance in the identification of the opaque minerals and to Dr. W. P. Staub for his aid in the preparation of the computer program. Dr. H. J. Klepser and Dr. L. A. Taylor made many helpful comments. Mr. L. S. Wiener and Mr. Carl Merschat of the North Carolina Division of Mineral Resources and Mr. Ed Bentzen of the Minerals Research Laboratory, North Carolina State University are also acknowledged for their help in locating several of the North Carolina deposits. I am also grateful to Dr. C. F. Faulkner and Dr. Gerald Schroeder of The University of Tennessee Anthropology Department who supplied the artifacts.

I am greatly indebted to Mr. S. G. Conrad of the North Carolina Division of Mineral Resources who arranged for funds to defray some of the expenses for the field work, X-ray analyses and preparation of this thesis.

I am also greatly indebted to my wife, Beverly, for her help in typing, drafting, proof reading, and for her patience throughout this study.

ABSTRACT

Several soapstone artifacts from Late Archaic-Early Woodland archaeological sites in Tennessee and ten soapstone deposits, two in South Carolina and eight in North Carolina were analyzed by X-ray diffraction, X-ray spectroscopy and petrographically in an attempt to correlate the artifacts and deposits. The data show that two of the deposits, Shelton Mine and Watermellon Branch, exhibit the best correlation with some of the artifacts. However, the evidence isn't conclusive.

Petrographic analysis revealed that the deposits and artifacts consist of one of two distinct mineral assemblages, one consisting of talc, chlorite, and anthophyllite, and a second in which talc, chlorite, and tremolite-actinolite comprise the assemblage. Two deposits, Leiceister #2 and Hammett Grove also contain appreciable biotite. No biotite is present in any of the artifacts. The deposits and artifacts possess textures ranging from strongly foliated, as in the Leiceister #2 deposit, to a massive or granoblastic texture, as in some of the Watermellon Branch samples.

Spectrographic analysis show that Cr, Mn, Ni, and Zn are the dominant trace elements present in the deposits and artifacts, with Cu, Sr, and Rb occurring in much smaller amounts. Five deposits have an average Ti content of less than 250 ppm while two deposits, Watermellon Branch and the Shelton Mine contain an average of 1863 and 800 ppm Ti, respectively. All of the artifacts except for the Polk, Campbell, and Jefferson County artifacts also contain appreciable Ti.

Although the purpose of this study was an attempt to correlate the artifacts and deposits, the data gathered also indicate that the deposits were derived from the alteration of an ultrabasic igneous rock rather than from a metasomatized carbonate.

TABLE OF CONTENTS

CHAPTER	PAGE
I. INTRODUCTION	1
Statement of the Problem	1
Location and Geology	3
Previous Investigations	7
II. METHODS OF ANALYSIS	9
Sample Collection and Preparation	9
Analysis by X-ray Fluorescence	10
X-ray Diffraction	11
Petrography	12
Heavy Mineral Analysis	12
III. PETROGRAPHY OF THE DEPOSITS	14
Introduction	14
Distinctive Characteristics of the Deposits	16
Correlation of Artifacts and Deposits	20
IV. X-RAY FLUORESCENCE	26
Introduction	26
Results of X-ray Fluorescence Analyses	27
V. INTERPRETATION OF DATA	38
Introduction	38
Attempts to Correlate Some Artifacts and Deposits Studied	38
Paragenetic Sequence	41

CHAPTER	PAGE
Comparison with Metamorphic Facies	42
Nature of the Parental Rock	46
Recommendations for Future Studies	52
BIBLIOGRAPHY	54
APPENDICES	58
Appendix A	59
Appendix B	61
Appendix C	71
VITA	110

LIST OF TABLES

TABLE	PAGE
1. Locations of Soapstone Deposits	2
2. Location of Artifact Sites in Tennessee	4
3. Comparison of the Mineral Compositions of the Deposits . .	17
4. Comparison of the Mineral Composition of the Artifacts . .	21
5. X-ray Fluorescence Analyses of the Deposits	28
6. X-ray Fluorescence Analyses of Artifacts	31
7. Average Trace Element Content of Deposits (ppm)	33
8. Average Trace Element Content of Selected Artifacts (ppm) .	35
9. Petrographic and Spectrographic Similarities Between the Shelton Mine and Watermellon Branch Deposits and Several Artifacts	40
10. Average Trace Element Content of Deposits (ppm)	49
11. Average Trace Element Content of the U.S.G.S. Rock Standards	50
12. Trace Element Content of Steatite Samples from Vermont Talc Deposits (ppm)	51

LIST OF FIGURES

FIGURE	PAGE
1. Location Map of Soapstone Deposits and Artifact Sites	5
2. ACF Diagram for the Quartz-Albite-Epidote-Biotite- Subfacies of the Greenschist Facies	44
3. ACF Diagram for the Staurolite-Almandine Subfacies of the Almandine-Amphibole Facies	45
4. Correlation Curve for Copper	62
5. Correlation Curve for Chromium	63
6. Correlation Curve for Manganese	64
7. Correlation Curve for Nickel	65
8. Correlation Curve for Rubidium	66
9. Correlation Curve for Strontium	67
10. Correlation Curve for Titanium	68
11. Correlation Curve for Zinc	69
12. Correlation Curve for Zirconium	70
13. Lepidoblastic Texture (Parallel or Subparallel Alignment of Biotite)	73
14. Large Flakes of Talc Prevalent in the Blue Rock Road Deposit	75
15. Acicular Form of Chlorite	77
16. Anomalous Blue Chlorite Replacing Gray Birefringent Chlorite	78
17. Fibrous Anthophyllite Partially Replaced by Talc	82

FIGURE	PAGE
18. Aggregate of Fan-Shaped Chlorite Flakes	84
19. Fibrous Anthophyllite Exhibiting Microfolds	85
20. Chlorite Concentrated Around Magnetite	88
21. Lepidoblastic Texture of Massive Talc	91
22. Randomly Oriented Tremolite-Actinolite in Fine-Grained Massive Talc	92
23. Chlorite Prophyroblasts Partially Replaced by Talc	94
24. Porphyroblast of Fluorapatite	95
25. Prismatic Grains of Tremolite-Actinolite Partially Replaced by Talc	97
26. Tremolite-Actinolite Partially Replaced by Talc	100
27. Porphyroblasts of Biotite and Talc in a Talc Matrix	101

CHAPTER I

INTRODUCTION

Statement of the Problem

The purpose of this study was to identify possible source areas for Late Archaic-Early Woodland (2000-300 B.C., Willey, pp. 256 & 267, 1966) soapstone artifacts which were used by the Tennessee Indians of that period. During the Late Archaic-Early Woodland period, soapstone was widely used by the aborigines of the eastern part of the country and artifacts can be found all along the Piedmont and Atlantic Coastal Plain from Georgia to New England (Willey, 1966, p. 258). The dominant use of the soapstone was for tub-like vessels and bowls. By learning something of the mineralogy and chemical composition of the artifacts and comparing this information with that from soapstone deposits, it was believed that potential source areas might be identified. With this information it would then be possible to establish trade routes which would aid us in understanding these early societies.

A preliminary investigation showed that several artifacts contained considerable nickel and chromium, which indicated that the artifacts were made from soapstone of ultramafic origin. Due to the abundance of ultramafic-related soapstone deposits in the eastern United States, it was decided to look at samples from several deposits rather than to study only one or two deposits in detail. With this in mind, ten deposits were sampled, eight in North Carolina and two in South Carolina (see Table 1). The study consisted of analyzing 57 samples

TABLE 1. Locations of soapstone deposits.

Deposit	County	North	East	Quad
<u>NORTH CAROLINA</u>				
Leiceister #2	Madison	712,700	919,200	192 N.W.
Watermellon Branch	Madison	803,600	920,900	191 N.W.
Shelton Mine	Madison	808,600	925,900	191 N.W.
Blue Rock Road	Yancey	792,150	1,057,450	209 N.W.
Blue Rock	Yancey	794,800	1,056,100	209 N.W.
Crabtree Creek	Mitchell	784,200	1,068,100	209 S.W.
Asbestos Mine	Jackson	522,100	801,000	176 S.E.
Asbestos Mine #2	Jackson	522,100	825,000	176 S.E.
<u>SOUTH CAROLINA</u>				
Paceolet River	Spartanburg	792,500	1,766,000	Spartanburg
Hammett Grove	Spartanburg	713,330	1,770,000	Spartanburg

from the soapstone deposits and comparing the results obtained for a similar study of 20 artifacts (see Table 2) using X-ray diffraction, X-ray fluorescence, petrographic and heavy mineral analysis techniques.

Location and Geology

The soapstone deposits sampled from North Carolina lie in an area underlain by gneisses, schists, and ultramafic and siliceous intrusions. The ultramafics are part of a discontinuous belt which extends along the Appalachians for a distance of more than 2000 miles from Alabama to New England. In North Carolina, this belt lies in the Blue Ridge Province, extending from the southwestern counties of Clay, Macon, and Jackson, and continuing northeastward through Transylvania, Haywood, Buncombe, Madison, Yancey, Mitchell, Avery, Watauga, Ashe, and Allegheny counties (Conrad et al., 1963). In this study two soapstone deposits from Jackson county, one from Mitchell county, three from Madison county, and two from Yancey County, North Carolina, and two from Spartanburg County, South Carolina, were sampled (see Figure 1).

The country rock consists of two primary types, the Carolina series which is comprised mainly of interlayered micaceous gneisses and schists and the Roan series which consists of interlayered hornblende gneisses and schists (Conrad, 1963). According to Conrad, the Carolina gneiss ranges in composition from muscovite-biotite gneiss, biotite gneiss, quartz-mica schist and quartzite, to garnet and kyanite-mica gneiss and schist. The Roan gneiss occurs interlayered with the Carolina gneiss and is distinguished from it by the presence of hornblende.

TABLE 2. Location of artifact sites in Tennessee.

Site	County	North	East	TVA Quad
Ha20	Hamilton	306,750'	2,272,250'	Snow Hill
Ha27	Hamilton	278,000'	2,256,300'	Daisy
Ha1	Hamilton	286,100'	2,258,750'	Daisy
Ck11	Cocke	650,000'	2,840,750'	Springvale
Pk1	Polk	294,750'	2,400,500'	Benton
Ld24	Loudon	466,000'	2,520,000'	Loudon
lJe	Jefferson	590,000'	2,765,500'	Shady Grove
Mr20	Monroe	434,400'	2,541,250'	Vonore
Cf34	Coffee	392,500'	1,929,250'	Ovoca
Mill	Marion	229,000'	2,135,000'	Sequatchie
4Cp5	Campbell	701,000'	2,526,500'	Jacksboro
By	Bradley	306,500'	2,386,250'	Benton

The schistose component of the Roan consists of hornblende, plagioclase, and quartz.

Acidic intrusions are common in this area. In Transylvania, Jackson, and Macon counties, the Whiteside granite is notable. Pegmatites, along with alaskite bodies, occur throughout this area and are especially abundant in the Spruce Pine area. Hess (1933) suggested that these acidic intrusions supplied the hydrothermal fluids which altered the ultramafics to the soapstone deposits.

Ultramafics occur throughout this area and are mainly dunites, saxonites, and pyroxenites. The dunites consist almost entirely of olivine with lesser amounts of chromite, enstatite, piccotite, and magnetite. Secondary minerals are serpentine, talc, vermiculite, chlorite, anthophyllite, and actinolite. The saxonites are composed primarily of olivine but they contain significant amounts of enstatite and bronzite. These orthopyroxenes occur as lath-shaped crystals up to an inch long disseminated through the olivine. The pyroxenites are composed predominantly of enstatite which occurs randomly as grains up to 6 inches long and 1-1/2 inches wide. Typically, the enstatite has suffered varying degrees of alteration resulting in the formation of fibrous anthophyllite, talc, and chlorite. Anthophyllite commonly occurs as pseudomorphs after enstatite, whereas the talc occurs surrounding the enstatite, along cleavage cracks, and as disseminated flakes. In some deposits the pyroxenites are completely replaced by anthophyllite and talc (Conrad, 1963). Pyroxenite bodies are considerably smaller than the dunite bodies. They are typically less than 400 feet long and most are from 100 to 200 feet wide.

The soapstone deposits sampled from South Carolina lie on the eastern flank of the Inner Piedmont belt, an area dominated by a hornblende gneiss unit which contains a variety of rock types. These rock types are gneisses and schists ranging in composition from garnet-bearing and garnet-free hornblende, diopside-hornblende, hornblende-diopside-biotite, diopside-labradorite, diopside-scapolite, hornblende-biotite-oligoclase, actinolite and chlorite schists. Also associated with this hornblende gneiss unit are small masses of hornblende gabbro, olivine gabbro, pyroxenite, peridotite, soapstone, granites, and pegmatites (Overstreet and Bell, 1965).

Previous Investigations

To the author's knowledge there has been only one previous investigation that has attempted to correlate soapstone artifacts with soapstone deposits. Allen et al. (unpublished) analyzed 40 samples from 24 different soapstone quarries in Virginia, Maryland, Pennsylvania, and North Carolina, and 30 artifacts from 17 different habitation sites in Virginia, Maryland, New York, and New Jersey for trace elements by neutron activation analysis. They found that they could distinguish deposits best by comparing the rare earth contents. Using this information they concluded that the soapstone artifacts found in the Shenandoah Valley, Virginia, came from a deposit in Madison County, North Carolina.

Studies dealing with the ultramafic soapstones include those by Hess (1933, 1936). In his 1933 paper, Hess stated that the ultramafic soapstones originated as a result of "steatization," a term he coined to

describe the hydrothermal alteration of an ultramafic body resulting in the formation of soapstone. Kulp and Brobst (1954) discussed the alteration of the Daybook dunite by a pegmatitic intrusion which resulted in the formation of a zone of talc, enstatite, anthophyllite, and serpentine adjacent to the pegmatite. Bain (1936), and Chidester (1962) also discussed the origin of soapstone from ultramafic rocks. Conrad et al. (1963) discussed the geology of the ultramafic belt of North Carolina in which soapstone bodies occur, as well as describing asbestos deposits with which soapstone is associated. Bentzen (1971, 1972) located several soapstone deposits in North Carolina. These were sampled to determine the amount and quality of the talc present to determine their economic potential. Overton (1969) reported the location of several soapstone deposits in South Carolina, two of which were sampled for this study.

CHAPTER II

METHODS OF ANALYSIS

Sample Collection and Preparation

In the field, samples were collected randomly across each deposit, care being taken to get a good representation of the deposit. Each suite was examined in the laboratory and several specimens were selected which were representative of each deposit. Thin sections were made from these selected samples for petrographic analysis. The remainder of each sample was broken in a jaw crusher and split several times until approximately 4 grams remained. This was ground with a mortar and pestle to pass a 220 mesh sieve.

Pellets were made of each sample by filling an aluminum cup (3 cm deep x 8 cm diameter) from 1/2 to 2/3 full of the 220 mesh sample and pressing at 4000 psi for 5 minutes. Pressed pellets are better than hand-packed samples because they are more uniform and because of their greater density, the X-ray intensities are increased. Also, pellets can be stored, allowing the same surface to be X-rayed several times. Pressed pellets do have the disadvantage that fine-grained and/or platy minerals may appear to be present in larger amounts (based on X-ray intensities) than they actually are.

In addition to the 57 collected samples, 4 samples were supplied by E. Bentzen of the Minerals Research Laboratory, North Carolina State University. These were representative samples of four deposits, the

Shelton Mine, Blue Rock, Watermellon Branch, and Crabtree Creek mines.

At the request of Dr. Charles Faulkner of the Anthropology Department, The University of Tennessee, who supplied some of the artifacts, only a portion of each artifact was prepared for analysis so that the entire specimen would not be destroyed.

Analysis by X-ray Fluorescence

All pelletized samples were analyzed by X-ray fluorescence for nine elements: Cu, Cr, Mn, Ni, Rb, Sr, Ti, Zn, and Zr. These elements were selected on the basis of several preliminary scans which indicated the occurrence of these elements in many of the samples. The analyses were conducted using a Phillips X-ray Spectrograph equipped with a lithium fluoride analyzing crystal. Except for Mn and Cr, all elements were analyzed with a chromium target X-ray tube. Due to the interference from the strong chromium peaks produced by the chromium tube in the areas of the $K\alpha$ peaks for Mn and Cr, a tungsten tube was used in analyzing for these elements. The spectrograph data in this study are based on the following operating parameters: Chromium tube operated at 35 KV and 30 Ma, or tungsten tube operated at 40 KV and 35 Ma, scintillation detector operated at 1 KV, baseline 150, window open, using the digital display system on the spectrograph data control panel from which counts per second (cps) data were taken. All samples were analyzed in a holder covered with 1/4 mil mylar film.

Standards were prepared from the six U. S. Geological Survey Rock Standards, G.-2 (granite, G.S.P.-1 (granodiorite), A.G.V.-1 (andesite),

B.C.R.-1 (basalt), D.T.S.-1 (dunite), and P.C.C.-1 (peridotite), using the same procedures used for preparing the samples. Preliminary spectrograph scans were made to establish peak and background positions for each element and to insure that there was no interference from other elements at these positions. Five 10-second readings were taken at each of these angular positions and converted to cps. From the means of these values the counting rates for each element was determined by calculating the background values at the K_{α} positions and subtracting these background values from the counting rates for the peak positions. From these cps data and from ppm data reported for the U.S.G.S. Rock Standards (Flanagan, 1969), correlation curves were prepared relating cps by X-ray fluorescence to ppm (Appendix A). A linear regression program was used to calculate the best fit line for the correlation curves.

To facilitate the calculation of the cps data a computer program (see discussion in Appendix B) was designed using a Wang 700 computer. This program was designed to take the cps data for the background positions, calculate their means and determine the cps value for the background at the peak position. This value is then subtracted from the mean cps value for the element at the peak position, giving the cps rate due to the element alone.

X-ray Diffraction

The pelletized samples analyzed with the spectrograph were also examined by X-ray diffraction to determine their mineralogical compositions. Analyses were conducted with a Norelco X-ray Diffractometer using Cu K_{α} radiation, a proportional detector, and a strip chart

recorder. All samples were scanned at the 200 scale and with a time constant of 2 seconds. Peaks which went off scale were rerun at scales of 1000 or 5000 depending on their intensities. Generally, the pellets were scanned from 5° to $50^{\circ} 2\theta$. All minerals were identified by use of the JCPDS reference files.

Petrography

A thin section was prepared from each sample prior to crushing. From these, each deposit and artifact was described on the basis of mineralogy and texture, and any unique characteristics which distinguished the deposits or artifacts were noted. The percentages of minerals in each section was based on visual estimates, several estimates being taken for each section.

Heavy Mineral Analysis

Several samples, two from each deposit and eleven artifacts, were selected for heavy mineral analysis to determine if this would aid in correlation. Splits were made of each crushed sample until approximately 4 grams remained. These were sieved and the size fraction from approximately 100 to 200 mesh was selected for separation using tetrabromoethane (S.G. = 2.9). The heavy fraction was removed, washed with methanol, and allowed to dry. In order to get an idea of the proportion of "heavies" in the deposits, each sample was weighed before and after separation using a Metler balance.

A polished section was made from a portion of each heavy mineral sample. The remainder of each sample was separated into groups of

similar minerals using a binocular microscope. Grains from each group were powdered and X-rayed for approximately one hour with the 57.3 mm camera or two hours using the 114.6 mm camera using Cu K α radiation at a setting of 35 KV and 17 Ma. The minerals were identified using the JCPDS reference files.

CHAPTER III

PETROGRAPHY OF THE DEPOSITS

Introduction

Samples from the deposits and artifacts fall into one of two distinct mineral assemblages. One consists of talc, anthophyllite, and chlorite and the other of talc, tremolite-actinolite, and chlorite. Six deposits, Leiceister #2, Blue Rock Road, Blue Rock, Crabtree Creek, Asbestos Mine, and Asbestos Mine #2, belong to the first group (talc, anthophyllite, and chlorite), while four deposits, Watermellon Branch, Shelton Mine, Paceolet River, and Hammet Grove, belong to the second group (talc, tremolite-actinolite, and chlorite). Two deposits, Leiceister #2 and Hammett Grove, contain appreciable biotite as well. The general characteristics of the deposits are summarized below. More complete descriptions of each deposit are given in Appendix C. Although the artifacts also consist of the same mineral suites as the deposits, the artifacts have been transported and therefore are not grouped together according to their mineral suites.

The rocks present in most of the deposits have a massive, non-foliated texture, but the rocks of the Leiceister #2, Watermellon Branch, and Asbestos Mine deposits are foliated. The fact that foliation is present at three of the deposits indicates that they may have undergone regional metamorphism after steatization took place, while the lack of foliation in the other deposits may indicate that they formed later than the last period of regional metamorphism.

Talc ranges in abundance from 30 percent in some Paceolet River samples to 90 percent in some of the Asbestos Mine #2 samples. The talc also differs in size and form. In the Hammett Grove deposit the talc occurs as small, acicular grains, generally less than 0.5 mm in length, whereas in the Blue Rock deposit it is present as porphyroblasts of lath-shaped flakes up to 4.0 mm in diameter. In this study the term porphyroblast is used only to denote grains which are distinctively larger than the surrounding grains and no genetic connotation is implied.

Chlorite ranges in abundance from less than 5 percent as in the Leiceister #2 and Blue Rock Road deposits to as much as 40 percent in some of the Blue Rock samples. The chlorite occurs in several forms and exhibits various distinctive characteristics. The most common variety is pleochroic, ranging from pale green to light brown, and has a first order gray birefringence. However, some of the chlorite in the Blue Rock Road, Blue Rock, and Crabtree Creek deposits has an anomalous blue birefringence. The chlorite ranges in shape from small, acicular grains less than 0.5 mm in length to porphyroblasts of lath-shaped flakes up to 4.0 mm in length such as in the Shelton Mine samples, while the chlorite of the Crabtree Creek deposit occurs in clusters of fan-shaped flakes.

The amphiboles, anthophyllite, and tremolite-actinolite, range in abundance from as little as 5 percent in the Blue Rock Road and Asbestos Mine #2 deposits to as much as 50 percent in some of the Asbestos Mine and Paceolet River samples. Although these two amphiboles usually do not occur together, two deposits, Leiceister #2 and Blue Rock, contain both amphiboles with anthophyllite being the dominant variety. Both

anthophyllite and tremolite-actinolite occur both as long, prismatic crystals (which are characteristic of the Leiceister #2 and Hammett Grove deposits) and as aggregates of fibrous grains (which are characteristic of the Asbestos Mine deposit). Although anthophyllite and tremolite-actinolite occur in similar forms, they are distinguished by their extinction angles. Monoclinic tremolite-actinolite has inclined extinction with $Z\wedge C$ ranging from 10° to 21° , whereas orthorhombic anthophyllite has parallel extinction.

Magnetite is the dominant opaque in the deposits, usually accounting for about .1 percent by volume of the bulk mineral assemblage. Rutile was identified in two deposits, the Watermellon Branch and the Shelton Mine. Apatite occurs in trace amounts in the Blue Rock, Watermellon Branch, and Shelton Mine samples. However, one sample from the Shelton Mine contains approximately 20 percent apatite. A few grains of chromite and ilmenite were also identified from the heavy mineral separations by the powder camera. Hematite occurs in all of the deposits, probably as an alteration product of the magnetite.

Distinctive Characteristics of the Deposits

While the deposits reported here are mineralogically similar, they do exhibit differences, as pointed out in the detailed descriptions of the deposits (see Appendix C). The distinctive characteristics are summarized below and in Table 3.

The presence of biotite is the most distinctive characteristic of two of the deposits, Leiceister #2 and Hammett Grove. Although both deposits contain biotite, they can be distinguished further by the

TABLE 3. Comparison of the mineral compositions of the deposits.

Deposit Minerals	Leiceis- ter #2 %	Blue Rock Rd. %	Blue Rock %	Crabtree Creek %	Asbestos Mine %	Asbestos Mine #2 %	Watermel- ion Br. %	Shelton Mine %	Paceolet River %	Hammett Grove %
talc	70-80	70-80	50-60	70-80	40-85	80-90	40-85	50-80	30-85	70-80
anthophyllite	5-10	tr-5	5-10	10-20	10-50	5-10	-----	-----	-----	-----
tremolite- actinolite	0-5	-----	1-5	-----	-----	-----	tr-50	10-15	5-60	10-20
chlorite (anoma- lous birefrig.)	-----	10-15	1-5	1-5	-----	-----	-----	1-3	-----	-----
chlorite (gray bifringence)	0-3	1-5	25-40	10-15	5-10	5-10	5-15	1-20	5-10	0-10
biotite	5-10	-----	-----	-----	-----	-----	-----	-----	0-1	0-10
magnetite	1-2	1-2	1	1	1	1	tr-1	1	1	1
rutile	-----	-----	-----	-----	-----	-----	0-1	trace	-----	-----
apatite	-----	-----	trace	-----	-----	-----	trace	tr-20	-----	-----
chromite	-----	trace	trace	-----	-----	-----	-----	-----	-----	-----
others	-----	-----	-----	-----	-----	-----	-----	-----	trace ilmenite	-----

presence of tremolite-actinolite in the Hammett Grove deposit and anthophyllite in Leiceister #2. Leiceister #2 rocks also possess well-pronounced foliation which is quite distinctive.

The abundance of talc, the predominance of anomalous blue, birefringent chlorite, and the minor amount of anthophyllite are distinctive features of the Blue Rock Road deposit. The Blue Rock and Crabtree Creek deposits are mineralogically similar to the Blue Rock Road deposit, but the Blue Rock and Crabtree Creek deposits contain only minor amounts of anomalous blue, birefringent chlorite. Also, talc is not as abundant in the Blue Rock deposit as it is in the Blue Rock Road deposit. The Crabtree Creek deposit contains nearly as much talc as Blue Rock Road, but the size of the flakes of the Crabtree Creek talc is generally smaller than the Blue Rock Road talc. The distribution of the chlorite is also somewhat distinctive. Both the Blue Rock and Crabtree Creek deposits contain clusters (or aggregates) of chlorite flakes, whereas the chlorite flakes of the Blue Rock Road deposit are distributed randomly as individual flakes. Although the distribution of the chlorite is similar in the Blue Rock and Crabtree Creek deposits, the individual flakes differ in form. The majority of the Crabtree Creek chlorite flakes exhibit a fan-shaped form, whereas the chlorite of the Blue Rock deposit displays a tabular shape.

The Asbestos Mine and Asbestos Mine #2 deposits are also mineralogically similar. Both consist of talc, anthophyllite, and chlorite. The Asbestos Mine #2 samples contain a greater percentage of talc, while the Asbestos Mine samples contain more anthophyllite. Also, the anthophyllite of the Asbestos Mine is predominantly fibrous in form,

whereas the anthophyllite of the Asbestos Mine #2 deposit has a long, prismatic form.

Four deposits, Watermellon Branch, Shelton Mine, Paceolet River, and Hammett Grove, contain tremolite-actinolite as the dominant amphibole. Both the Watermellon Branch and Shelton Mine deposits contain rutile. However, the rutile is more uniformly distributed in the Shelton Mine samples, whereas in the Watermellon Branch deposit, one sample contains approximately 1 percent rutile and a sample collected approximately 20 feet away contains no rutile. Although the Shelton Mine does contain rutile it is not as abundant as it is in one Watermellon Branch sample which contains approximately 1 percent rutile. The Shelton Mine also contains apatite, which was not observed in the Watermellon Branch samples. The most distinctive feature of the Shelton Mine is the occurrence of large chlorite porphyroblasts. No other deposit contains chlorite similar in size and form to the Shelton Mine chlorite porphyroblasts.

The Hammett Grove and Paceolet River deposits are distinguished by the presence of biotite in many of the Hammett Grove samples. Although biotite was observed in the Paceolet River samples, it occurs in only one sample and in a trace amount. In the Hammett Grove deposit, biotite occurs in several samples and comprises approximately 10 percent of the samples. The talc content is also slightly greater in the Hammett Grove deposit than in the Paceolet River deposit.

Correlation of Artifacts and Deposits

It is realized that only a few deposits and artifacts have been examined in this study. The comparisons which follow are intended to illustrate the kind of comparisons and correlations which can be made on the basis of mineralogical and petrological characteristics. It is obvious that a particular artifact or suite of artifacts may have come from a deposit which was not included in this study. Even so, the source area must have had similar mineralogical and petrological characteristics (and presumably a similar origin) to the deposit(s) cited. To aid in correlation, the minerals and their abundances for each artifact are listed in Table 4. Detailed descriptions are given in Appendix C. A comparison of Table 3, page 17, and Table 4 illustrates the general similarity between samples from the deposits and artifacts. However, like the deposits, the artifacts also exhibit differences. The fact that none of the artifacts contain chlorite with anomalous blue birefringence makes it unlikely that the Blue Rock Road, Blue Rock, and Crabtree Creek deposits are source areas for the artifacts, since these deposits contain anomalous birefringent chlorite. The absence of aggregates of chlorite flakes in any of the artifacts adds further evidence that the Blue Rock and Crabtree Creek deposits were not source areas since both deposits contain aggregates of chlorite.

One artifact, 59/40Cf34, contains biotite. Leicester #2 and the Hammett Grove deposits have up to 10 percent biotite. However, only Leicester #2 contains anthophyllite as does artifact 59/40Cf34. The artifact contains 30-40 percent anthophyllite, whereas the Leicester #2

TABLE 4. Comparison of the mineral composition of the artifacts.

Artifact Minerals	111-376/ 7Ha1 %	29/ 21Ha20 %	159/ 65Ha20 %	10/ 66Ha20 %	28/ Ha27 %	212/ 40Cf34 %	232/ 40Cf34 %	111/ 40Cf34 %	59/ 40Cf34 %	61 & 85/ 40Cf34 %	432/ 1Je %	433/ 1Je %	F-12/ 40Ck11 %	144/ 40Ld24 %	1008/ 2Pk1 %	115/ 2Pk1 %
talc	50-60	50-60	30-40	30-40	30-40	45-55	45-55	45-55	45-55	75-85	80-85	80-85	80-85	60-65	85-90	75-80
anthophyllite	25-30	25-30	-----	-----	-----	-----	-----	-----	30-40	5-10	2-5	-----	-----	-----	-----	-----
tremolite- actinolite	-----	-----	30-40	30-40	30-40	20-30	20-30	20-30	-----	-----	-----	-----	-----	-----	-----	-----
chlorite (gray birefringent)	15-20	15-20	20-30	20-30	20-30	20-30	20-30	20-30	2-4	2-4	10-15	15-20	15-20	35-40	10-15	15-20
chlorite (anomalous)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
biotite	-----	-----	-----	-----	-----	-----	-----	-----	5-10	-----	-----	-----	-----	-----	-----	-----
magnetite	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
rutile	trace	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
apatite	-----	-----	-----	trace	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
ilmenite	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

samples contain less than 10 percent anthophyllite. Both Leiceister #2 and the artifact contain less than 5 percent chlorite. The correlation between 59/40Cf34 and Leiceister #2 isn't exact, but their mineral assemblages are quite similar and on the basis of petrographic analyses, Leiceister #2 can be considered as a possible source area for artifact 59/40Cf34.

Two Coffee County artifacts, 61/ and 85/40Cf34, contain anthophyllite as the principle amphibole, but they contain more talc, 75-85 percent, than the other Coffee County artifacts. Two deposits, Leiceister #2 and Asbestos Mine #2, contain mineral suites similar to artifacts 61/ and 85/40Cf34. They both contain more than 70 percent talc, 5-10 percent anthophyllite, and less than 10 percent chlorite. However, the Leiceister #2 deposit contains biotite while these two artifacts and the Asbestos Mine #2 deposit contains no biotite. Thus, the Asbestos Mine #2 deposit exhibits the best mineralogical correlation with artifacts 61/ and 85/40Cf34. However, texturally these artifacts aren't similar to the Asbestos Mine #2. Most notable is the lack of fibrous anthophyllite in the artifacts.

Three Coffee County artifacts, 212/, 232/, and 111/40Cf34 are quite similar. They all contain 45-55 percent talc, 20-30 percent tremolite-actinolite, and 20-30 percent chlorite. Samples from three deposits, Watermellon Branch, Shelton Mine, and Paceolet River, exhibit the best mineralogical correlation with these artifacts. The talc content of these three deposits ranges from 40-80 percent, the tremolite-actinolite ranges from a trace to 50 percent in the Watermellon Branch samples, from 10-15 percent in the Shelton Mine samples, and from

5-60 percent of the Paceolet River samples. Based on the low tremolite-actinolite content and the presence of chlorite porphyroblasts in the Shelton Mine samples, which are not present in these artifacts, it appears that the artifacts did not come from the Shelton Mine deposit. However, the Watermellon Branch and Paceolet River deposits may be possible source areas for these artifacts.

Artifacts from Hamilton County, like those from Coffee County possess two distinct mineral assemblages. Artifacts III-376/7Hal and 29/21Ha20 consist of 50-60 percent talc, 25-30 percent anthophyllite, and 15-20 percent chlorite. The Blue Rock and Asbestos Mine deposits contain mineral suites similar to these two artifacts. However, the Blue Rock deposit contains (minor) tremolite-actinolite and anomalous blue birefringent chlorite which do not occur in the artifacts. Thus, the Asbestos Mine samples are the only ones which are mineralogically similar to the artifacts III-376/7Hal and 29/21Ha20. However, the artifacts do not contain fibrous anthophyllite which is prevalent in the Asbestos Mine samples.

The other Hamilton County artifacts, 159/65Ha20, 10/66Ha20, and 28/Ha27, consist of 30-40 percent talc, 0-40 percent tremolite-actinolite, and 20-30 percent chlorite. Samples from the Watermellon Branch, Shelton Mine and Paceolet River deposits contain mineral assemblages similar to these artifacts. However, the chlorite of the artifacts is not as large as the prophyroblasts of chlorite in the Shelton Mine deposit. And since all of the Shelton Mine samples contain chlorite prophyroblasts it is unlikely the Shelton Mine was the source area for these artifacts. The Watermellon Branch and Paceolet River deposits may be source

areas on the basis of mineral composition.

Two artifacts from Jefferson County were examined and found to be very similar in texture and mineralogy. They consist of 80-85 percent talc, 10-20 percent chlorite, and 0-5 percent anthophyllite. The Asbestos Mine #2 deposit is the only deposit studied which has a mineral composition comparable to the Jefferson County artifacts. Samples from the Asbestos Mine #2 deposit consist of 80-90 percent talc, 5-10 percent chlorite, and 5-10 percent anthophyllite, which correlates well with the Jefferson County artifacts.

The Cocke County artifact, F-12/40Ck11, and the Loudon County artifact, 144/40Ld24, are quite similar to the Jefferson County artifacts. The Cocke County artifact contains 80-85 percent talc and 15-20 percent chlorite. Neither artifact contains an amphibole, but chlorite is more abundant in the Loudon County than in the Jefferson and Cocke County artifacts. Both the Cocke and Loudon County artifacts are also texturally similar to the Jefferson County artifacts and they too may have come from the Asbestos Mine #2 deposit.

The Polk County artifacts, 1008/2Pk1 and 115/2Pk1, contain large amounts of talc. 1008/2Pk1 contains 75-90 percent talc and 115/2Pk1 has 75-80 percent. 115/2Pk1 contains from 2-5 percent tremolite-actinolite, while 1008/2Pk1 has no amphibole. Both artifacts contain from 10-15 percent chlorite. The chlorite is similar to the chlorite of the Shelton Mine in that it occurs as porphyroblasts, many of which are partially altered to talc. Also, like the Shelton Mine, a trace of apatite occurs in these artifacts. Some of the Shelton Mine samples correlate quite well with the Polk County artifacts and thus may be considered a potential source area.

Four artifacts from Monroe County were examined and found to be quite similar. They consist of 50-60 percent talc, 20-30 percent tremolite-actinolite, and 20-30 percent chlorite. The Watermellon Branch, Shelton Mine, Paceolet River, and Hammett Grove deposits contain mineral assemblages comparable to the Monroe County artifacts; however, the Hammett Grove samples contain at least 80 percent talc, which is greater than the talc content of the artifacts. Samples from the Watermellon Branch and the Paceolet River deposits contain as little as 50 percent talc, which is more comparable to the talc content of the Monroe County artifacts.

Based on the petrographic study several things can be stated about the possibility of the deposits in this study being source areas for the artifacts. The Blue Rock Road, the Blue Rock, and the Crabtree Creek deposits do not appear to be good source areas for the artifacts studied because they contain anomalous blue birefringent chlorite and aggregates of chlorite flakes. The Asbestos Mine deposit shows a mineral composition comparable to artifacts III-376/7Hal and 29/21Ha20, Asbestos Mine #2 has a mineral composition similar to artifacts 61/, 85/, and 232/40Cf34 and 233/1Je, F-12/40Ck11, and 144/40Ld24, the Shelton Mine's mineralogy is comparable to artifacts 1008/ and 115/2Pk1, the Watermellon Branch and Paceolet River deposits are possible source areas for artifacts 212/, 232/, and 111/40Cf34, 159/, 10/, and 28/Ha, and the 40Mr's; and the Leiceister #2 is somewhat similar to artifact 59/40Cf34. Thus, some of the artifacts may have come from some of the deposits analyzed in this study. At least they came from comparable deposits, based on mineralogical and petrological criteria.

CHAPTER IV

X-RAY FLUORESCENCE

Introduction

X-ray fluorescence analyses were conducted on several samples from each deposit and on each of the artifacts. The samples were prepared and analyzed using the procedures discussed in Chapter II. The spectrograph readings (cps) were converted to ppm using the correlation curves discussed in Appendix A.

The samples were analyzed for nine trace elements which had been detected in one or more of the samples in preliminary scans. In general order of abundance, these elements were: Cr, Mn, Ni, Zn, Ti, Cu, Sr, Rb, and Zr. Most of the samples had detectable Cr, Mn, Ni, and Zn. Seven had detectable Ti. Cu, Rb, and Sr occurred in very small amounts in most of the samples while Zr was detected in only two samples which were 99 percent chlorite. None of the talc samples contained zirconium.

The accuracy of X-ray fluorescence data increases as the number of counts taken increases. In this study sufficient counts were taken for the major trace elements, Cr, Mn, Ni, and Ti to insure an accuracy of at least ± 1.0 percent at a one sigma confidence level, 2.0 percent at a two sigma confidence level and 3.0 percent at a three sigma confidence level.

The accuracy of one zinc value reported ranges from 1.8 percent to 1.0 percent at one sigma, 3.5 percent to 2.0 percent at two sigma, and 5.3 percent to 3.0 percent at three sigma. The other elements,

Rb, Cu, and Sr have greater percentages of error from the reported values due to their smaller concentrations.

Results of X-ray Fluorescence Analyses

Results of the X-ray fluorescence analysis of the deposits and artifacts are listed in Tables 5 and 6. The average of each of the trace elements for the samples of each deposit was taken and tabulated (see Table 7) to facilitate in the correlation of the deposits with each other and with the artifacts.

Generally, the trace element composition of the rocks in each deposit is quite similar (Table 7). Seven of the deposits have an average chromium content between 1800 and 2300 ppm. The Blue Rock Road deposit has only 969 ppm chromium while the Asbestos Mine and Asbestos Mine #2 deposits average 5685 and 5725 ppm chromium, respectively. The nickel content is fairly consistent among the deposits, with the average content ranging from a low of 1028 ppm for the Shelton Mine to a high of 2133 ppm for the Blue Rock deposit. The average manganese content of the deposits is also generally the same, ranging from 987 ppm to 1731 ppm, with the exception of the Asbestos Mine #2 deposit which has an average of only 570 ppm. The titanium content displays the greatest difference among the deposits. Three deposits, Blue Rock Road, Asbestos Mine, and Asbestos Mine #2, contain no detectable titanium. Five deposits have an average of less than 250 ppm Ti, while the Watermelon Branch and the Shelton Mine deposits contain average titanium contents of 800 and 1863 ppm, respectively. All of the Shelton Mine samples contain appreciable amounts of titanium, ranging from 1100 to 3100 ppm.

TABLE 5. X-ray fluorescence analyses of the deposits.

Sample	Cu	Cr	Mn	Ni	Rb	Sr	Ti	Zn	Zr
Leiceister									
1-S	10(3)*	2375(303)	1480(330)	1620(585)	14(8)	12(3)	100(21)	338(93)	0(-1)
1-M	3(1)	2425(307)	955(221)	1340(486)	2(-5)	16(6)	100(22)	262(77)	0(-17)
1-S-C	7(2)	2000(260)	1425(327)	1580(566)	8(2)	22(13)	20(13)	200(64)	0(1)
Watermellon Branch									
2-R	7(2)	3125(384)	1040(238)	1500(538)	0(-7)	7(-4)	1600(176)	338(93)	0(-5)
2-L	0(-20)	1575(212)	210(649)	1810(649)	26(22)	22(13)	0(5)	180(60)	0(1)
2-F	0(-8)	850(134)	1710(393)	800(290)	8(2)	25(16)	9600(688)	318(89)	0(71)
Shelton Mine									
3-A	0(-18)	1425(198)	410(90)	1700(608)	1(-6)	10(1)	1100(91)	180(60)	0(2)
3	14(4)	2150(276)	1660(372)	1310(473)	8(2)	20(9)	1550(121)	228(70)	0(2)
3-N	45(14)	2450(310)	1300(299)	480(182)	2(-5)	45(38)	1700(131)	338(93)	0(-6)
3-W	33(10)	1525(208)	1600(367)	620(228)	20(16)	16(6)	3100(228)	324(90)	0(22)
Blue Rock Road									
4-M	30(9)	825(144)	1000(229)	2040(730)	0(-14)	17(0)	0(14)	91(42)	0(6)
4-F	7(2)	0(47)	1040(238)	1360(491)	3(-3)	12(3)	0(16)	143(52)	0(-26)
4-N	0(-5)	1575(213)	1015(233)	1600(576)	10(5)	12(3)	0(10)	167(57)	0(3)
4-S	7(2)	1475(202)	1330(304)	2160(771)	20(16)	10(-1)	0(11)	185(61)	0(-11)
Blue Rock									
5-A	10(3)	2000(260)	1240(284)	2020(724)	0(-23)	11(2)	110(19)	96(42)	0(-2)
5-B	0(-3)	2825(352)	1460(335)	2180(779)	2(-5)	0(-11)	110(18)	81(39)	0(-12)
5-C	0(-1)	1900(250)	1250(286)	2200(787)	8(2)	6(-6)	70(16)	67(36)	0(0)

TABLE 5. (Continued)

Sample	Cu	Cr	Mn	Ni	Rb	Sr	Ti	Zn	Zr
Crabtree Creek									
6-A	13(4)	2775(346)	540(123)	1480(533)	4(-2)	7(-3)	400(39)	304(86)	0(20)
6-B	0(-2)	2050(267)	920(212)	2080(739)	0(-8)	6(-4)	100(20)	105(44)	0(-10)
6-C	7(2)	2050(265)	1210(278)	2200(786)	7(1)	50(44)	50(15)	86(40)	0(-10)
6-D	0(-5)	2025(262)	1740(400)	1900(681)	0(-9)	9(-2)	50(15)	129(49)	0(-8)
Hammett Grove									
H.G.-2	97(28)	2000(261)	1080(248)	2520(899)	0(-8)	25(15)	0(3)	100(43)	0(-10)
H.G.-10	7(2)	175(60)	2720(625)	320(122)	21(17)	760(825)	11200(805)	370(101)	290(408)
H.G.-3	7(2)	2050(266)	1550(356)	1060(388)	9(3)	5(-7)	100(22)	76(38)	0(-10)
H.G.-11	30(8)	1675(224)	2460(564)	1520(551)	5(-1)	11(2)	30(14)	115(46)	0(1)
Paceolet River									
P.R.-3	0(-4)	1800(239)	920(210)	1520(547)	18(12)	33(24)	200(27)	120(47)	0(31)
P.R.-6	23(7)	2150(276)	550(126)	1050(383)	30(27)	23(13)	100(23)	67(36)	0(-5)
P.R.-7	30(9)	2150(275)	1700(390)	1030(375)	3(-4)	33(24)	100(22)	67(36)	0(6)
P.R.-8	0(-8)	300(73)	1350(311)	720(269)	0(-12)	40(33)	2050(155)	228(70)	140(259)
Asbestos Mine									
A.B.-1	63(19)	8000(1301)	2480(569)	580(215)	5(-1)	9(-2)	0(10)	200(64)	0(-11)
A.B.-4	53(16)	3825(462)	1595(365)	760(277)	0(-10)	20(9)	0(9)	36(49)	0(-3)
A.F.-7	56(17)	4550(542)	1310(301)	940(344)	10(4)	7(3)	0(7)	138(35)	0(-6)
A.B.-8	0(-4)	6125(716)	1540(353)	3200(1119)	0(-12)	12(-3)	0(0)	62(51)	0(7)
Asbestos Mine #2									
X-2	10(3)	7025(815)	590(135)	1730(622)	0(-18)	6(-6)	0(5)	270(79)	0(0)
X-3	40(12)	4425(525)	550(126)	2080(391)	0(-19)	11(2)	0(6)	134(30)	0(0)

TABLE 5. (Continued)

Sample	Cu	Cr	Mn	Mi	Rb	Sr	Ti	Zn	Zr
3993	23(7)	2423(308)	1050(241)	200(515)	5(-2)	27(12)	100(12)	100(31)	0(-1)
4016	30(9)	2625(329)	1280(293)	1920(688)	5(-1)	25(14)	100(21)	44(31)	0(-1)
3996	0(-5)	2200(281)	1650(379)	1720(616)	3(-3)	10(1)	300(31)	115(46)	0(23)
4015	23(7)	2325(273)	1090(250)	2100(755)	4(-2)	20(11)	0(9)	143(52)	0(-5)

*The cps are given in parentheses.

TABLE 6. X-ray fluorescence analyses of artifacts.

Sample	Cu	Cr	Mn	Ni	Rb	Sr	Ti	Zn	Zr
Coffee County									
212/40Cf34	33(10)*	4075(488)	1640(376)	720(267)	7(1)	20(10)	1500(117)	105(44)	0(25)
232/40Cf34	53(16)	3500(426)	2050(471)	500(219)	10(4)	17(7)	300(66)	200(64)	0(6)
61/40Cf34	23(7)	1625(218)	1700(406)	1700(608)	0(-8)	5(-7)	0(7)	67(36)	0(-3)
59/40Cf34	23(7)	2050(265)	2190(503)	700(256)	0(-9)	9(-2)	1000(84)	200(65)	0(0)
Campbell County									
44/40Cp	27(8)	1850(243)	340(77)	1330(481)	6(0)	1(-9)	0(13)	63(35)	0(1)
Monroe County									
308/40Mr20	40(12)	2175(279)	1840(422)	720(265)	12(6)	25(14)	2800(219)	139(60)	0(51)
291/40Mr20	20(6)	2750(343)	1775(407)	820(302)	0(-7)	20(10)	3050(227)	276(80)	0(62)
166/40Mr25	63(18)	1550(212)	1510(347)	580(215)	20(17)	38(25)	2200(169)	180(60)	0(45)
137/40Mr20	0(-2)	2325(296)	1650(374)	840(309)	0(-9)	12(3)	2100(150)	105(44)	0(-35)
Madison County									
1475/60M111	30(9)	4500(531)	3300(799)	1880(672)	12(6)	35(26)	4200(308)	167(57)	0(55)
Polk County									
1003/2PrL	0(-9)	8000(1096)	720(164)	1380(498)	0(-10)	9(-2)	0(12)	484(124)	0(10)
Bradley County									
7271/By	0(-6)	1925(252)	1675(384)	1000(361)	0(-8)	52(45)	3350(247)	110(43)	0(117)

TABLE 6. (Continued)

Sample	Cu	Cr	Mn	Ni	Rb	Sr	Ti	Zn	Zr
Hamilton County									
10/66Ha10	0(-2)	1925(253)	1710(392)	1180(427)	4(-2)	0(-11)	3100(231)	152(53)	0(90)
29/Ha20	0(0)	5125(604)	1690(387)	1500(536)	0(-9)	20(10)	50(15)	96(42)	0(7)
III-376/7Hal	23(7)	3775(453)	1750(402)	880(322)	3(-3)	35(28)	1750(133)	129(49)	0(99)
28/Ha29	0(0)	1775(235)	1520(350)	880(317)	2(-5)	31(23)	2050(156)	129(80)	0(163)
Jefferson County									
432/1Je	30(9)	2175(280)	550(125)	1180(425)	9(3)	18(8)	100(18)		0(0)
433/1Je	0(-1)	2500(315)	805(185)	2340(833)	0(-8)	105(105)	280(30)	200(64)	0(0)
Rhea County									
2Rh41	36(11)	525(99)	1575(361)	1320(475)	6(0)	38(29)	1900(145)	67(57)	0(34)
Loudon County									
144/40Ld24	0(-2)	2800(349)	1250(286)	1890(677)	10(5)	16(7)	750(55)	62(56)	0(-11)
Cocke County									
F-12/40Ck	0(-2)	2225(285)	1050(240)	1060(387)	8(2)	18(8)	1050(85)	57(55)	0(47)

*The cps are given in parentheses.

However, the Ti content of the Watermelon Branch samples display greater variation. One sample, 2-L, contains no detectable titanium, another sample, 2-F, contains 9600 ppm, while still another sample, 2-R contains only 1600 ppm. The heavy mineral content of 2-R is predominantly rutile which accounts for its titanium content. Sample 2-F is composed predominantly of chlorite with minor talc. Chidester (1962) stated that titanium can substitute for iron and magnesium in chlorite. Deer, Howie, and Zussman (1962) also stated that Ti can occur in chlorite, substituting for Fe and Mg. They give analyses of several chlorites which contain as many as 0.138 Ti ions out of a total of 32 ions. A heavy mineral separation was not conducted on sample 2-F and rutile may be present in it also.

The Zn, Cu, Rb, and Sr contents of the rocks in these deposits are similar, although some samples differ more than others. The average zinc content ranges from 81 to 279 ppm, copper from 2 to 45 ppm, rubidium from 0 to 11 ppm, and strontium from 6 to 30 ppm. Zirconium was detected in only two samples, H.G.-11 and P.R.-8, both of which consist predominantly of chlorite.

The trace element composition of the artifacts is similar to that of the deposits (see Table 8). Like the deposits, Cr, Mn, Ni, and Ti are the most abundant trace elements, with minor Zn. Very small amounts of Cu, Rb, and Sr are present while Zr was not detected. The titanium content displays the greatest range among the artifacts. It ranges from an average of 190 ppm for the Jefferson County artifacts to a high of 4200 ppm for the Madison County artifact.

Since artifacts from the same county come from the same or from sites which are located near each other, the average of their data was taken and tabulated in Table 8.

The Coffee County artifacts (40Cf34) are characterized by relatively high contents of Cr and Mn. Cr averages 2813 ppm and Mn averages 1913. Also notable is the low Ni concentration, which averages only 930 ppm. However, one Coffee County artifact has a Ni content of 1700 ppm. One of the Coffee County artifacts contains no detectable Ti, while the other three have Ti concentrations of 100, 1000, and 1500 ppm.

The Monroe County artifacts (40Mr), are quite similar to each other in trace element composition. The Cr content of these artifacts averages 2200 ppm and ranges from 1550 to 3750 ppm, Mn averages 1694 ppm and ranges from 1510 to 1840 ppm, Ni averages 740 ppm and ranges from 580 to 840 ppm, and the Ti content averages 2538 ppm, ranging from 2100 to 3050 ppm. The relatively low Ni and relatively high Ti concentrations are the most distinguishing characteristics of these artifacts.

The Hamilton County artifacts (Ha), exhibit more diversity in their trace element concentration than the Monroe County artifacts. The Cr content of the four artifacts averages 3650 ppm and ranges from 1775 to 5125 ppm. Two of the artifacts, 10/66Ha10 and 28/Ha29, contain 1925 and 1775 ppm Cr, respectively, while the other two artifacts, 29/Ha20 and III-376/7Hal, contain 5125 and 3775 ppm Cr, respectively. This distinct difference in Cr content between the artifacts may be a reflection of their mineralogy. Artifacts 10/66Ha20 and 28/Ha29 consist of talc, tremolite-actinolite, and chlorite, while artifacts 29/Ha20 and III-376/7Hal consist of talc, anthophyllite, and chlorite. The Hamilton County

artifacts may have come from different deposits.

Two artifacts from a site in Jefferson County (1Je) were analyzed and with the exception of Ni they contain essentially the same trace element concentrations. Their Cr content ranges from 2175 to 2500 ppm, Mn ranges from 550 to 805 ppm, Ti from 100 to 280 ppm, and Ni from 1180 to 2340 ppm. The low Mn content is the most distinguishing trace element feature of these artifacts.

Seven other artifacts, all from different counties, are also listed in Table 4, page 21. As can be seen from Table 4, the most distinguishing characteristic of artifact 85Vt is its low Cr content of only 525 ppm. Artifact 1008/2Pk1 is characterized by a relatively high concentration of Cr, containing more than 8000 ppm, and a low Mn content of 720 ppm. Artifact 4Cp5 from Campbell County also has a low Mn content, only 340 ppm. However, unlike the Polk County artifact, its Cr content is only 1850 ppm, a content characteristic of several deposits. The Madison County artifact, 40Mi, has relatively high Cr, Mn, and Ti contents, with Cr being 4500 ppm, Mn being 3300 ppm, and Ti equaling 4200 ppm. These concentrations are unlike those of any of the deposits. Artifact 7271/By is characterized by a relatively high Ti content, 3750 ppm, with the other trace elements being near the average for rock from this type of deposit. The trace element content of the Loudon County, 40Ld, and Cocke County, 40Ck, artifacts are quite similar. These artifacts are also mineralogically similar in that neither contains amphibole. However, the Cocke County artifact contains more talc than the Loudon County artifact does.

CHAPTER V

INTERPRETATION OF DATA

Introduction

Based on petrographic and spectrographic analyses it is possible to distinguish between many of the deposits and to determine whether they are possible source areas for the soapstone artifacts. However, the results of this study are not conclusive enough to state for certain that a specific deposit is definitely the source area for any single artifact. Some of the artifacts which came from a given site show distinctive mineralogical and/or textural differences. This may suggest that they originated in more than one source area (soapstone deposit). Alternatively, such artifacts may simply reflect such variations that may occur in a single deposit, such as the Watermellon Branch deposit (see descriptions in Appendix C). The data does suggest that some of the deposits are not likely source areas while others could be source areas. The data also suggest that the deposits were derived from the alteration of ultrabasic igneous rocks rather than from metasomatized carbonate rocks.

Attempts to Correlate Some Artifacts and Deposits Studied

Of the deposits studied several show similarities to some of the artifacts but only two deposits, Shelton Mine and Watermellon Branch,

exhibit enough similarities with some of the artifacts to be considered as possible source areas. Artifacts 144/40Ld24, F12/40Ck11, 10/66Ha20, 28/Ha27, and the four Monroe County (Mr) artifacts exhibit several characteristics which are similar to those of the Shelton Mine and Watermellon Branch deposits (see Table 9).

The main distinction between the Shelton Mine samples and the artifacts is the absence of chlorite porphyroblasts and minor anomalous blue birefringent chlorite from the artifacts. However, the Shelton Mine samples are similar mineralogically and in trace element content to artifacts 144/40Ld24, F12/40Ck11, 10/66Ha27, and the Monroe County artifacts (see Table 9). Thus, based on the data it is difficult to state for certain that the Shelton Mine is or is not a possible source area for these artifacts.

The Watermellon Branch samples are also mineralogically and spectrographically similar to artifacts 144/40Ld24, F12/40Ck11, 10/66Ha20, 28/Ha27 and the Monroe County artifacts (see Table 9). Unlike the Shelton Mine samples there is no anomalous blue chlorite in the Watermellon Branch samples, nor do they contain chlorite porphyroblasts which are characteristic of the Shelton Mine samples. However, it is difficult to correlate the Watermellon Branch samples and the artifacts based on textural evidence due to the diverse textures displayed by the Watermellon Branch samples which range from a well-foliated texture to a nonfoliated granoblastic texture.

Although the data aren't conclusive the Shelton Mine and Watermellon Branch samples do display several similarities to artifacts 144/40Ld24, F12/40Ck11, 10/66Ha20, 28/Ha27, and the 40Mr artifacts.

TABLE 9. Petrographic and spectrographic similarities between the Shelton Mine and Watermellon Br. ch deposits and several artifacts.

Characteristic	Shelton Mine	Watermellon Br.	144/ 40Ld24	F-12/ 40Ck11	10/ 66Ha20	28/ Ha27	40Mr*
Percent talc	50-80%	40-85%	60-65%	80-85%	30-40%	30-40%	70-80%
Amphibole	Tr-Act	Tr-Act	Tr-Act	Tr-Act	Tr-Act	Tr-Act	Tr-Act
Birefringence of Chlorite	gray, minor anomalous blue	gray	gray	gray	gray	gray	gray
Texture	chlorite por- phyroblasts	strong foliation to granoblastic	non- foliated	non- foliated	non- foliated	non- foliated	non- foliated
Accessory minerals	rutile, apatite, magnetite	rutile, apatite, magnetite	magne- tite	magne- tite	magne- tite	magne- tite	magne- tite
<u>Trace Elements</u>							
Cu	1888 ppm	2350 ppm	2800 ppm	2225 ppm	1925 ppm	1775 ppm	2200 ppm
Mn	1243 ppm	625 ppm	1250 ppm	1050 ppm	1710 ppm	880 ppm	2694 ppm
Ni	1028 ppm	1655 ppm	1890 ppm	1000 ppm	1180 ppm	880 ppm	740 ppm
Ti	1863 ppm	800 ppm	750 ppm	1050 ppm	3100 ppm	2050 ppm	2538 ppm

*Average of four samples.

Based on the data of this study the Shelton Mine and Watermellon Branch deposits can be considered possible source areas for these artifacts.

In summary, on the basis of spectrographic and petrographic analyses it appears that only samples from the Watermellon Branch and Shelton Mine Deposits have mineralogies and trace element concentrations comparable to any of the artifacts; i.e., 144/40Ld24, F12/40Ck11, 10/66Ha10, 28/Ha27, and the Monroe County artifacts (40Mr). The artifacts could have come from either of these deposits or a similar deposit. However, the evidence isn't conclusive.

The other artifacts may have similarities either petrographically or in trace element content, but not in both, which indicates that the other artifacts of this study probably did not come from any of the deposits examined in this study. On the basis of trace element content it is apparent that all of the artifacts exhibit trace element contents similar to those of soapstones derived from ultramafic rocks. In searching for the source area of these artifacts, deposits of ultramafic origin should be given prime consideration.

Paragenetic Sequence

Textural evidence suggests that the minerals of the deposits did not form at the same time. Each deposit is characterized by alteration features. The amphiboles, tremolite-actionolite and anthophyllite, often occurred originally as euhedral to subhedral grains which are not partially altered to talc and/or chlorite. Such pseudomorphs (talc and chlorite after amphiboles) occur in many of the deposits. This suggests that the amphiboles are among the earliest-formed minerals. It

may well be that pyroxenes and/or olivine or serpentine preceded the formation of amphiboles (somewhat like Bowen's Reaction Series for igneous rocks) but evidence for these minerals is not preserved either texturally or by armored relicts preserved in the rocks. Talc is often found cutting across and replacing chlorite indicating that at least some of the talc was formed later than the chlorite. Biotite, when present, appears to be later than the amphiboles, but earlier than the chlorite. Some of the biotite grains appear to be pseudomorphs after amphibole. Thus, the paragenetic sequence is as follows: amphiboles formed "earliest" (at least the oldest species preserved), then biotite, chlorite, and talc formed last. This sequence indicates an environment of decreasing temperature, similar to the one described by Hess (1933), and Chidester (1962), for the soapstone deposits of Virginia and Vermont, respectively, which they attribute to hydrothermal alteration of ultramafics.

Comparison with Metamorphic Facies

The mineral assemblages which comprise the deposits examined in this study can be expressed graphically by ACF diagrams which illustrate the physical and chemical conditions under which they were formed.

The assemblage talc, tremolite-actinolite, and chlorite, characteristic of four deposits studied, occurs under physico-chemical conditions comparable to the greenschist facies of Barrovian regional metamorphism. Within the greenschist facies, this assemblage occurs in the quartz-albite-epidote-biotite subfacies, which begins at a temperature around 450-470°C and ends with the disappearance of

actinolite at approximately 500°C (Winkler, 1967). Winkler (1967) noted that the assemblage, talc + actinolite + chlorite \pm biotite \pm quartz is characteristic of metamorphosed ultrabasic rocks at conditions of this subfacies. The assemblage of talc, chlorite, and tremolite-actinolite occurs in the FeO-MgO corner of the quartz-albite-epidote-biotite ACF diagram (Figure 2). Two of the deposits, Leiceister #2 and Hammett Grove, contain approximately 10 percent biotite which indicates that these deposits have a higher potassium content than the other deposits. Such mineral assemblages can be expressed using A'KF diagrams (Thompson, 1957).

The deposits composed of talc, chlorite, and anthophyllite have a mineral assemblage which is stable at higher temperatures and pressures (comparable to a slightly higher grade of metamorphism) than the talc, chlorite, tremolite-actinolite assemblage. In Barrovian metamorphism, anthophyllite does not form until the almandine-amphibolite facies is reached, occurring in the staurolite-almandine subfacies (Figure 3). Chlorite and talc are not normally stable under the conditions of this subfacies (Winkler, 1967), but as stated in the previous section, the mineral assemblages of these deposits are not in equilibrium, as evidenced by the later alteration of the anthophyllite to talc and chlorite. The presence of relict anthophyllite suggests that the physical conditions of the staurolite-almandine subfacies were reached and maintained for sufficient time for anthophyllite to form in sufficient quantities and of sufficient size to be preserved even though later alteration took place. Whether these conditions were reached during the period of cooling of the ultramafic intrusions or during

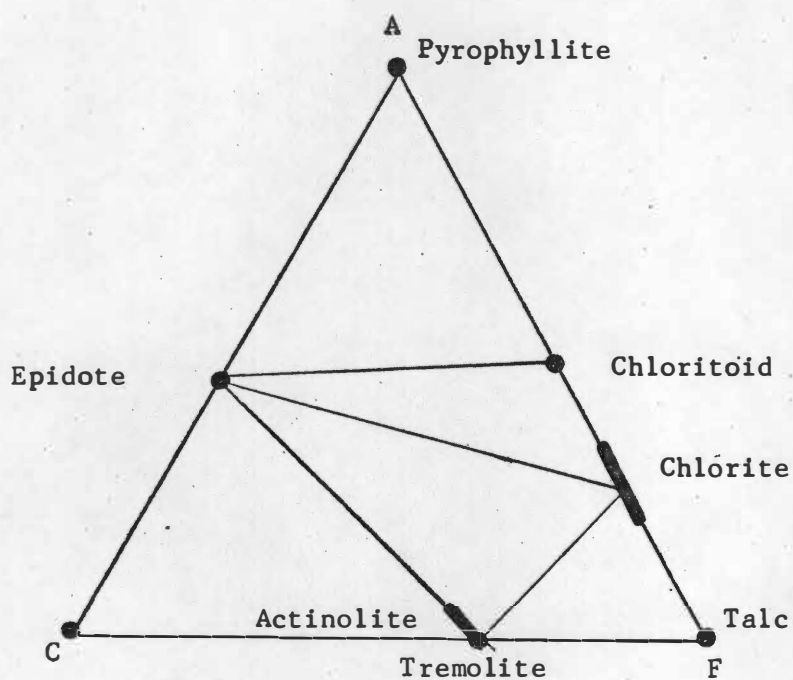


FIGURE 2. ACF diagram for the quartz-albite-epidote-biotite-subfacies of the greenschist facies.

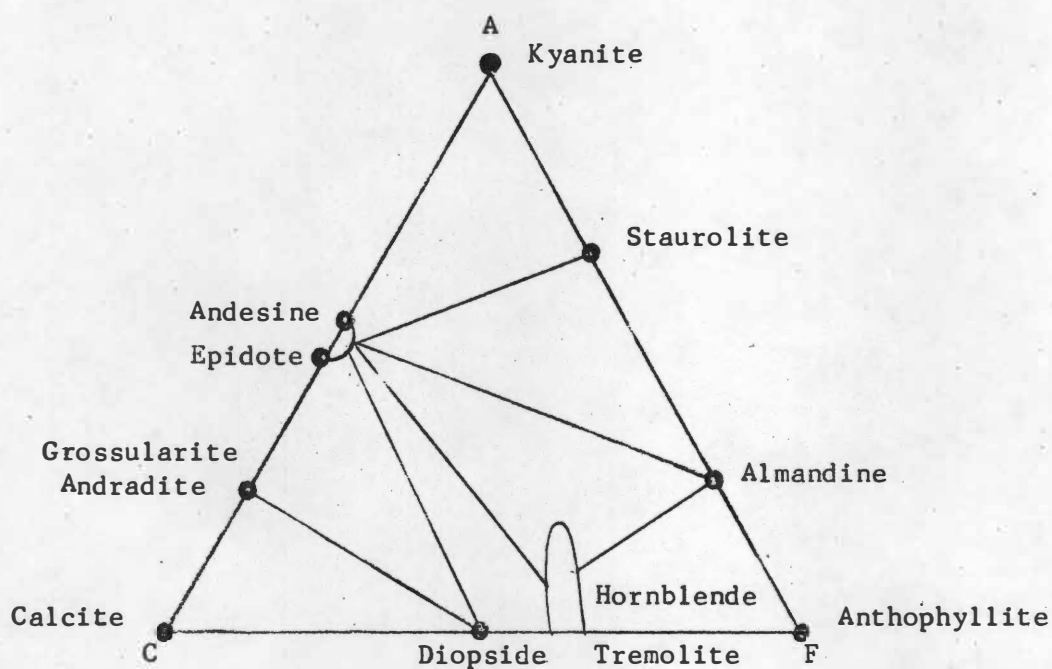


FIGURE 3. ACF diagram for the staurolite-almandine subfacies of the almandine-amphibole facies.

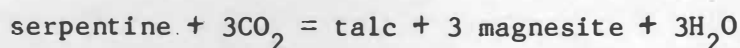
a subsequent reheating of such a body cannot be determined from the available evidence.

Nature of the Parental Rock

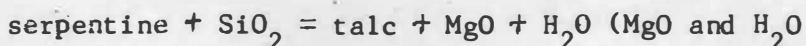
There are two genetic types of talc deposits, one formed by the alteration of siliceous carbonates and another which involves the hydrothermal alteration of a mafic or ultramafic body. The data of this study suggest that the deposits of this study were formed by the latter process.

Petrographically, the absence of carbonate minerals from the samples studied is difficult to explain if these deposits were produced by the metamorphism of siliceous carbonates. Miyashiro (1973, p. 272) in a discussion of the progressive metamorphism of siliceous carbonates stated "Under most $\text{CO}_2/\text{H}_2\text{O}$ ratios, talc is the first mineral to form in metamorphosed siliceous dolomitic limestones: $3 \text{ dolomite} + 4 \text{ quartz} = \text{H}_2\text{O} + 3 \text{ calcite} + 3\text{CO}_2 + 1 \text{ talc}$. Thus, according to Miyashiro, the formation of talc by metamorphism of a siliceous dolomitic limestone results in the formation of talc and calcite.

The absence of carbonate minerals in the thin sections studied also suggests that the hydrothermal fluids must have been low in CO_2 . Carbon dioxide metasomatism of a mafic or ultramafic rock should result in the formation of talc and a carbonate mineral as expressed by Turner (1948) in the following reaction:



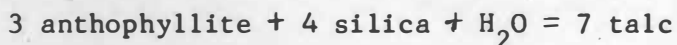
Silica metasomatism of an ultramafic rock results only in the formation of talc, which Turner (1948) expressed by the following reaction:



being removed in solution)

Turner (1948) stated that, "Evidence that magnesia is expelled during replacement of serpentine by talc is seen in the reaction zones of chlorite schist that commonly form in rock adjacent to bodies of serpentine that have been so affected (by silica metasomatism)." The above reaction would account for the absence of carbonate minerals in the samples of this report. Turner (1948) also stated that the parent rock need not be serpentine, but that unserpentinized peridotites may also be converted to soapstone either directly or by an intermediate stage of hydrothermal metamorphism marked by transitory development of actinolite-chlorite. Thus, the deposits in which talc, chlorite, and tremolite-actinolite comprise the mineral assemblage, may be examples of this transition stage since the samples show evidence of the alteration of actinolite and chlorite to talc. Float blocks consisting almost entirely of chlorite, were found at several of the deposits and may represent the reaction zone where magnesia is expelled during metasomatism, as described by Turner (1948).

Silica metasomatism could also account for the deposits in which talc, chlorite, and anthophyllite comprise the mineral assemblage. Bowen and Tuttle's studies (1949) showed that the addition of silica to anthophyllite can result in the formation of talc:



They concluded that anthophyllite will develop as an intermediate phase in the formation of talc from anhydrous material. Fyfe (1962) in his study of the relative stability of talc, anthophyllite, and enstatite,

showed that it is possible to convert enstatite + quartz to anthophyllite in the presence of water at temperatures near 760°C at 1 Kb pressure. Yoder (1952) and Roy and Roy (1955) concluded that anthophyllite is a stable phase of the system $\text{MgO-SiO}_2\text{-H}_2\text{O}$ only in water-deficient regions. Yoder (1952, p. 612) also stated that anthophyllite will remain stable at temperatures below 660°C in water-deficient systems. This evidence indicates that the talc, chlorite, anthophyllite deposits of this study could be ultramafics altered by silica metasomatism in a water-deficient system.

X-ray spectrographic data also support an origin by alteration of ultramafic rocks for the deposits of this study. As can be seen in Table 10, most of the deposits contain appreciable amounts of Cr, Mn, and Ni. Although carbonate rocks may contain Mn, they typically don't contain Cr and Ni in the amounts present in the deposits of this study. Comparison of the average trace element content of the deposits with that of the U.S.G.S. Rock Standards (see Tables 10 and 11) makes it evident that the deposits of this study have trace element compositions comparable to those of the peridotite (PCC-1) and dunite (DTS-1) standards.

Chidester's studies (1963) of some Vermont talc deposits, which he attributed to an ultramafic parent rock, revealed a trace element content (see Table 12) similar to that of the soapstone samples in this study. Although Chidester's samples are steatite, which is composed of 99 percent talc, they do show a strong resemblance to the trace element content in the deposits of this study.

TABLE 11. Average trace element content of the U.S.G.S. Rock Standards.

Element	G-2	GSP-1	AGV-1	PCC-1	DTS-1	BCR-1
Cu	10.7	35.2	63.7	10.4	7.9	22.4
Cr	9.0	13.2	12.9	3090	4230	16.3
Mn	265	326	728	899	926	1350
Ni	6.4	10.7	17.8	2430	2330	15.0
Rb	234	343	89.4	0.5	2.8	72.8
Sr	463	247	657	0.3	-----	345
Ti	3030	4322.5	6575	62.5	47.5	17866.7
Zn	74.9	143	112	53	61	132
Zr	316	544	227	-----	-----	185

TABLE 12. Trace element content of steatite samples from Vermont talc deposits (ppm).

Element	CA-8	CA-3	W-23
Cr	2000 ppm	2500 ppm	2000 ppm
Mn	700 ppm	1500 ppm	700 ppm
Ni	1600 ppm	1500 ppm	1600 ppm
Ti	200 ppm	100 ppm	100 ppm

Other evidence supporting ultramafic parental rocks include the abundance of ultramafic intrusions in the area of the deposits, and Bentzen's (1972) study of several of the soapstone deposits of North Carolina, three of which were analyzed in this study. Bentzen stated that the magnetites from the deposits are chromium bearing and that the deposits have a Fe/Mg ratio very similar to the dunite intrusions of North Carolina.

Based on the available data, the hydrothermally altered ultramafic origin appears to best fit the deposits studied here.

Recommendations for Future Studies

In this study pressed pellets were used for X-ray spectrographic analysis. The pellets were made from samples which had been sieved to 220 mesh. However, these samples still consisted of grains which may have microabsorption effects. To insure greater uniformity of samples in future analyses of this type, it would be advisable to fuse the sample prior to pelletizing and to add a heavy absorber to reduce matrix effects.

Also, in future studies it might be beneficial to analyze the opaques in greater detail. The elemental content of the opaques might differ from deposit to deposit and could aid in distinguishing between the deposits. This could also aid in interpreting the origin of deposits since chromium rich magnetites might explain the scarcity of chromite in the deposits of the type analyzed in this study.

All of the deposits analyzed in this study are located in North and South Carolina. Since these deposits are separated from the artifact sites in Tennessee by the Appalaichian Mountains, it was suggested by one of the Faculty Committee members (Dr. Larson) that in any future study it might be beneficial to analyze deposits which would have been more accessible to the Indians, such as the soapstone deposits of Georgia and Virginia.

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APPENDICES

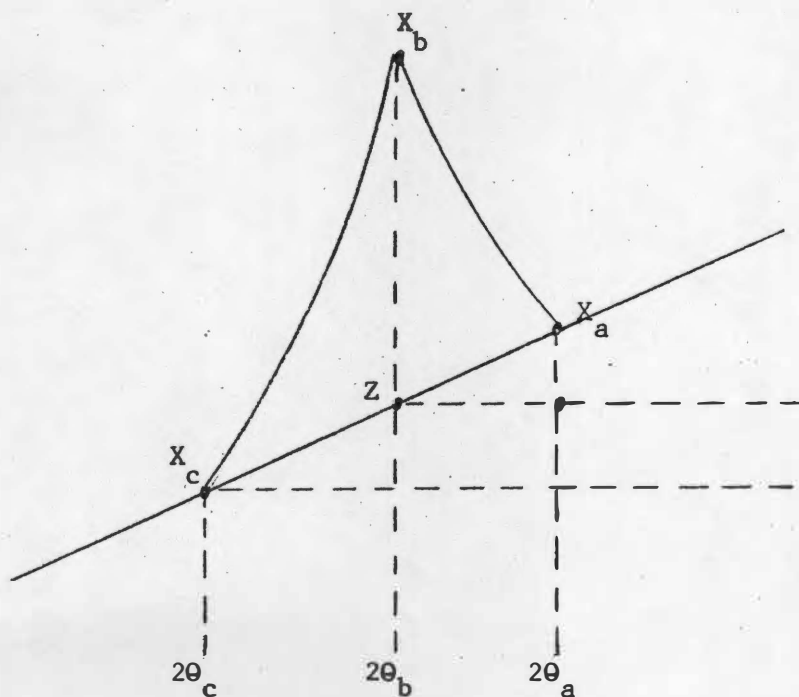
APPENDIX A

PROGRAM FOR DETERMINING PEAK INTENSITIES

The equation,

$$Q = X_b - (X_c - \frac{(2\theta_c - 2\theta_b)(X_c - X_a)}{(2\theta_c - 2\theta_a)})$$

was devised to determine the cps value at a peak position minus the cps background value at that same peak position. The equation was derived from the following relationship:



X_a = cps value for background at the angular position $2\theta_a$
 X_b = cps value at the peak position
 X_c = cps value for background at the angular position $2\theta_c$
 Z = background value at the peak position where:

$$Z = X_c - \frac{(2\theta_c - 2\theta_b)(X_c - X_a)}{(2\theta_c - 2\theta_a)}$$

First the program determines the mean value of the cps for each of the angular positions of peak and background. Then using these mean values it determines the background value at the peak position (Z).

This value (Z) is then subtracted from the mean cps value at the peak position (X_b) giving the cps value of the peak (Q). Thus the cps value of the peak minus the background value at that position is derived.

The equation is based on the principle of similar triangles. With the slope and angles of similar triangles being the same, the ratio of the sides are the same also. The equation is based on the ratio of line $X_c - X_a$ to $2\theta_c - 2\theta_a$ and $X_c - Z$ to $2\theta_c - 2\theta_b$, with $Zx_c 2\theta_b$ and $X_a X_c 2\theta_a$ representing the similar triangles.

The equation was derived as follows:

$$\frac{(2\theta_c - 2\theta_b)}{(2\theta_c - 2\theta_a)} = \frac{(X_c - Z)}{(X_c - X_a)} \quad \text{Cross multiplication gives you the equation:}$$

$$(2\theta_c - 2\theta_b)(X_c - X_a) = (X_c - Z)(2\theta_c - 2\theta_a) \quad \text{Dividing both sides by the right side gives you:}$$

$$\frac{(2\theta_c - 2\theta_b)(X_c - X_a)}{(X_c - Z)(2\theta_c - 2\theta_a)} = 1 \quad \text{Multiplying both sides by } (X_c - Z) \text{ gives you:}$$

$$\frac{(2\theta_c - 2\theta_b)(X_c - X_a)}{(2\theta_c - 2\theta_a)} = (X_c - Z) \quad \text{Subtracting } X_c \text{ from both sides gives you:}$$

$$\frac{(2\theta_c - 2\theta_b)(X_c - X_a)}{(2\theta_c - 2\theta_a)} - X_c = -Z \quad \text{Multiplying both sides by } -1 \text{ gives you:}$$

$$X_c - \left(\frac{(2\theta_c - 2\theta_b)(X_c - X_a)}{(2\theta_c - 2\theta_a)} \right) = Z$$

APPENDIX B

CORRELATION CURVES

The following correlation curves (Figures 4 through 12) were used to convert cps readings obtained from X-ray fluorescence to ppm. The U.S.G.S. Rock Standards (Flanagan, 1969) were used as the standards for the curves. A best fit line for each element is plotted. Confidence levels of 50 percent and 90 percent are also plotted for each curve to aid in illustrating the range for each element.

In the curves the following symbols are used:

_____	= Best Fit Line
____ _	= 50 percent Confidence Level
____ _	= 90 percent Confidence Level

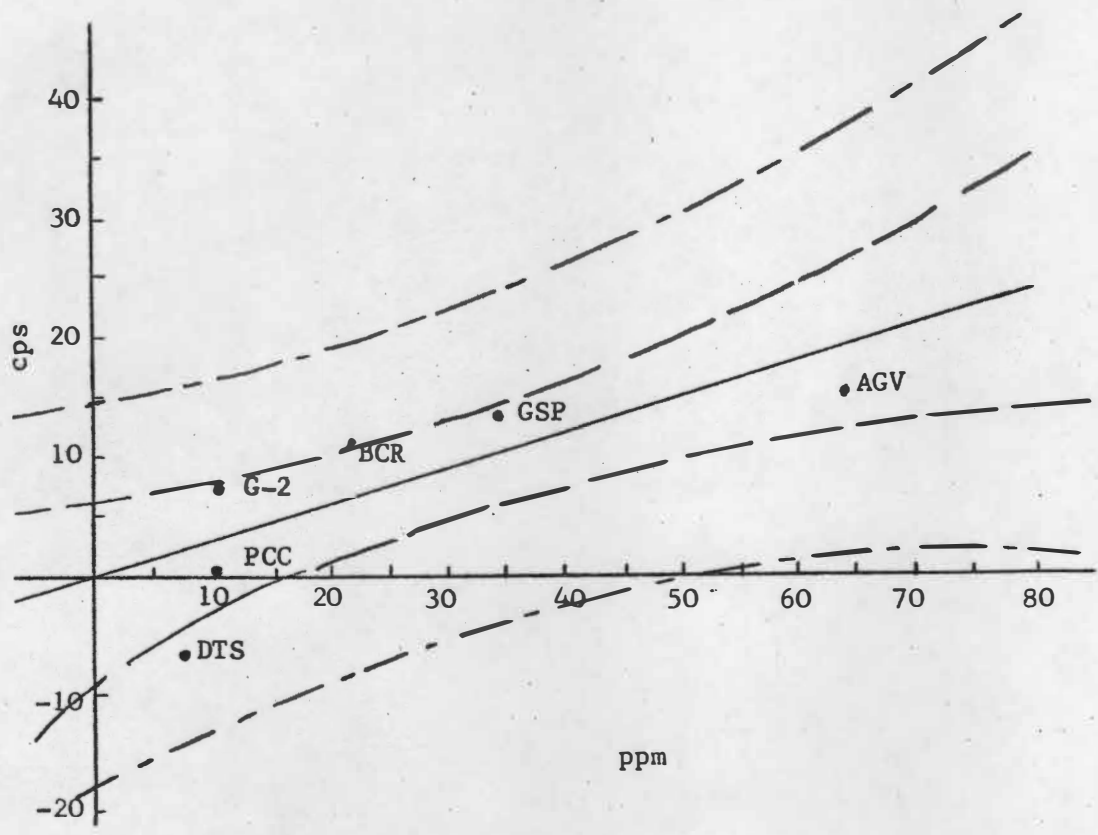


FIGURE 4. Correlation curve for copper.

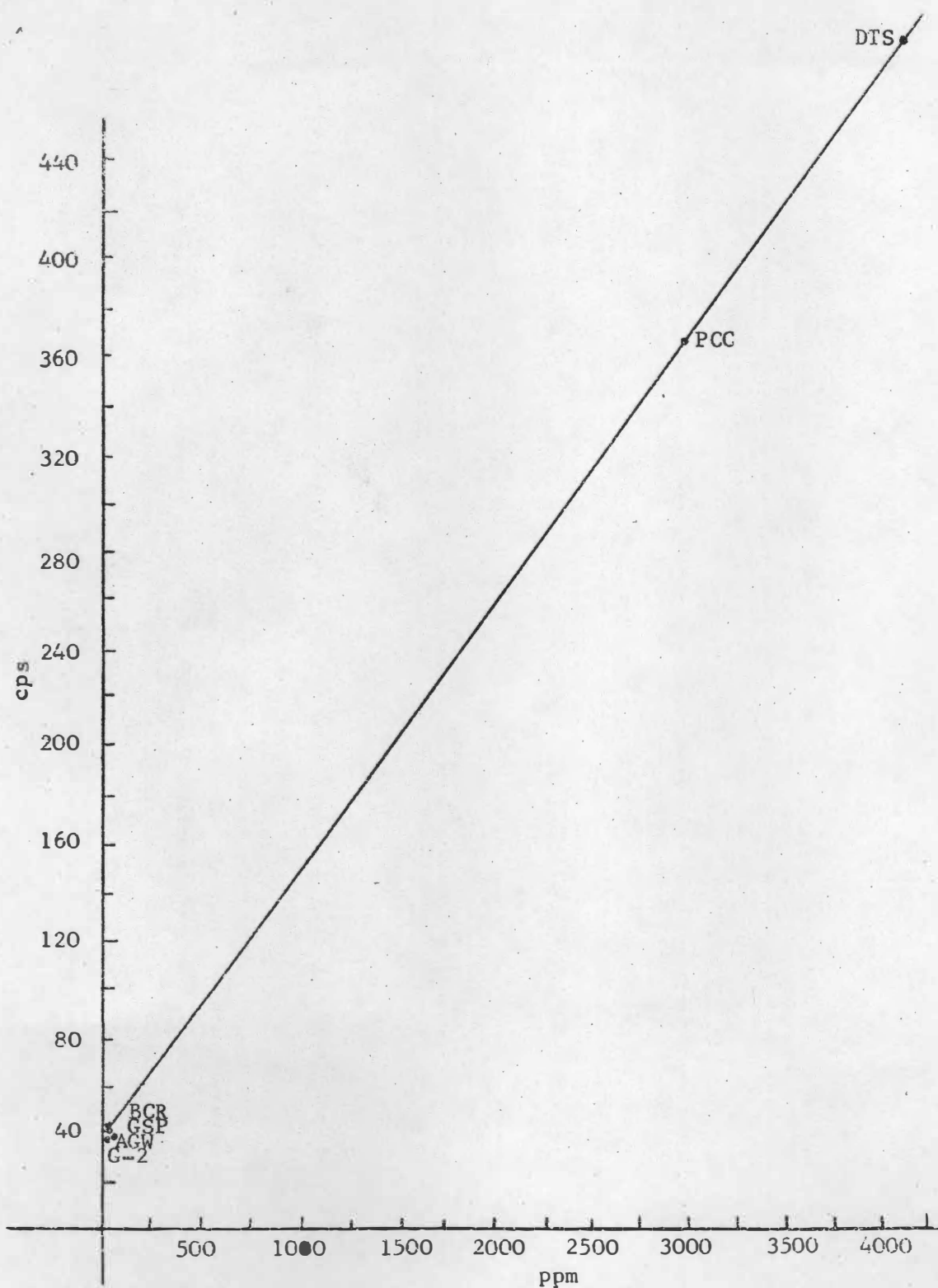


FIGURE 5. Correlation curve for chromium.

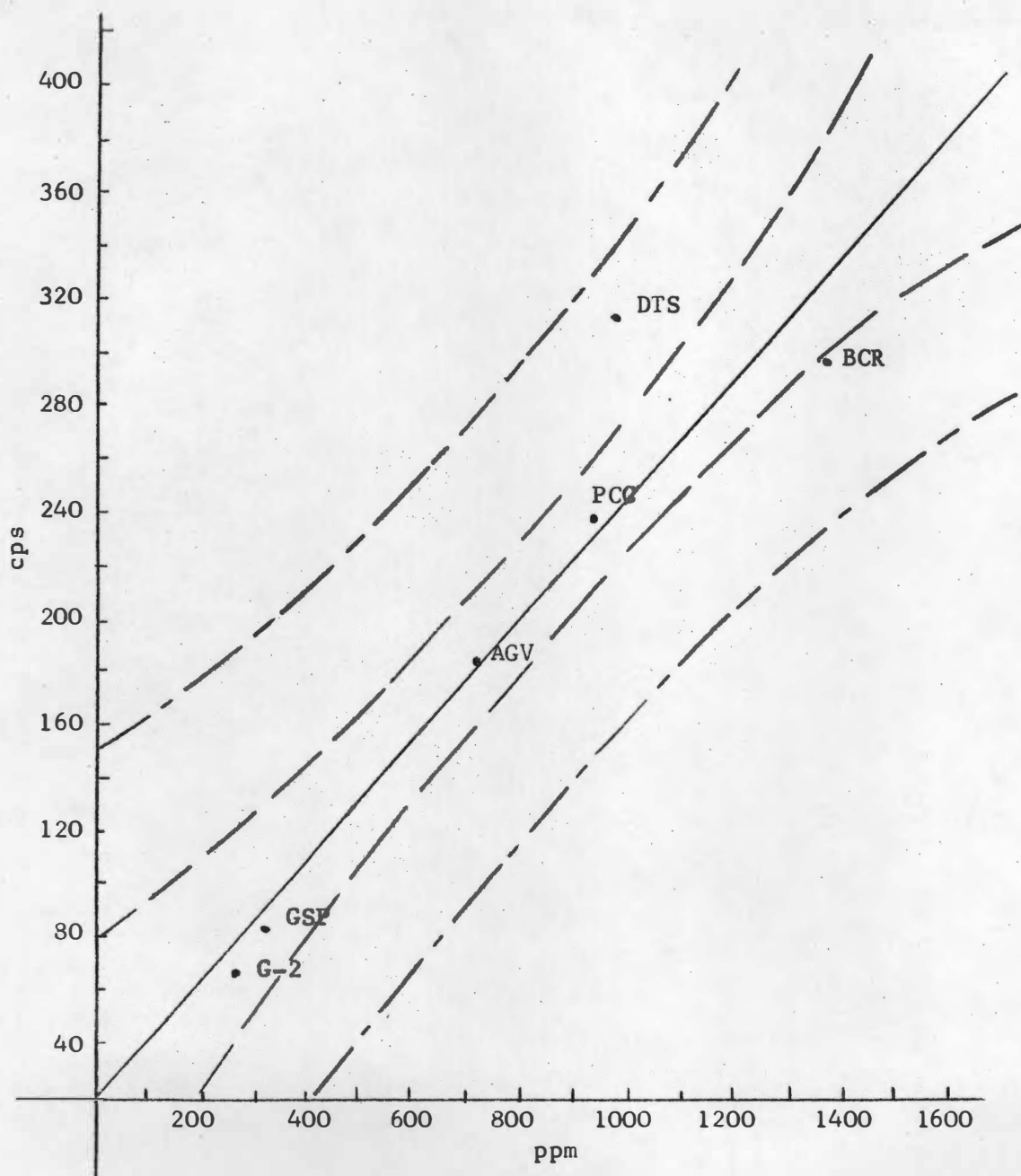


FIGURE 6. Correlation curve for manganese.

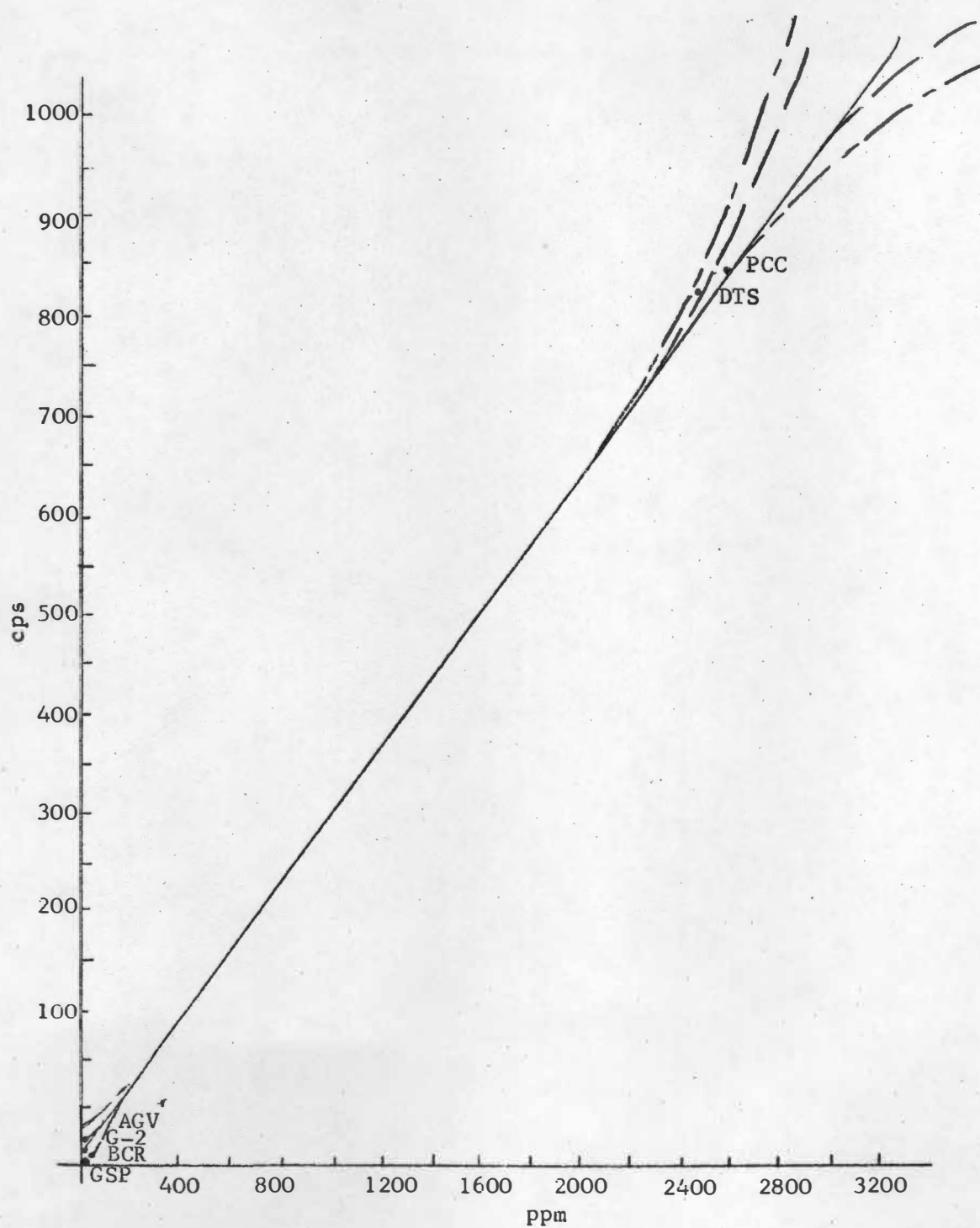


FIGURE 7. Correlation curve for nickel.

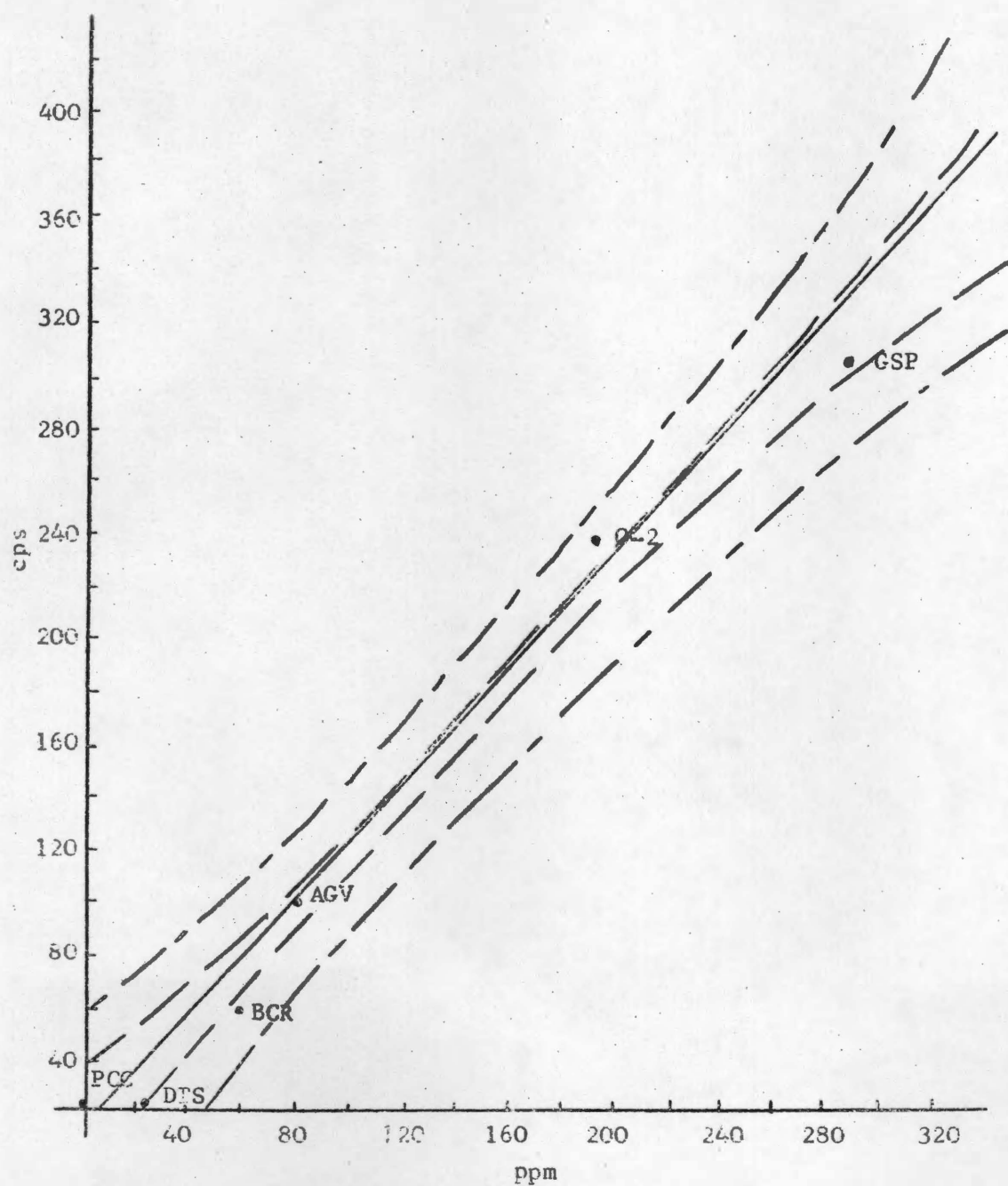


FIGURE 8. Correlation curve for radium.

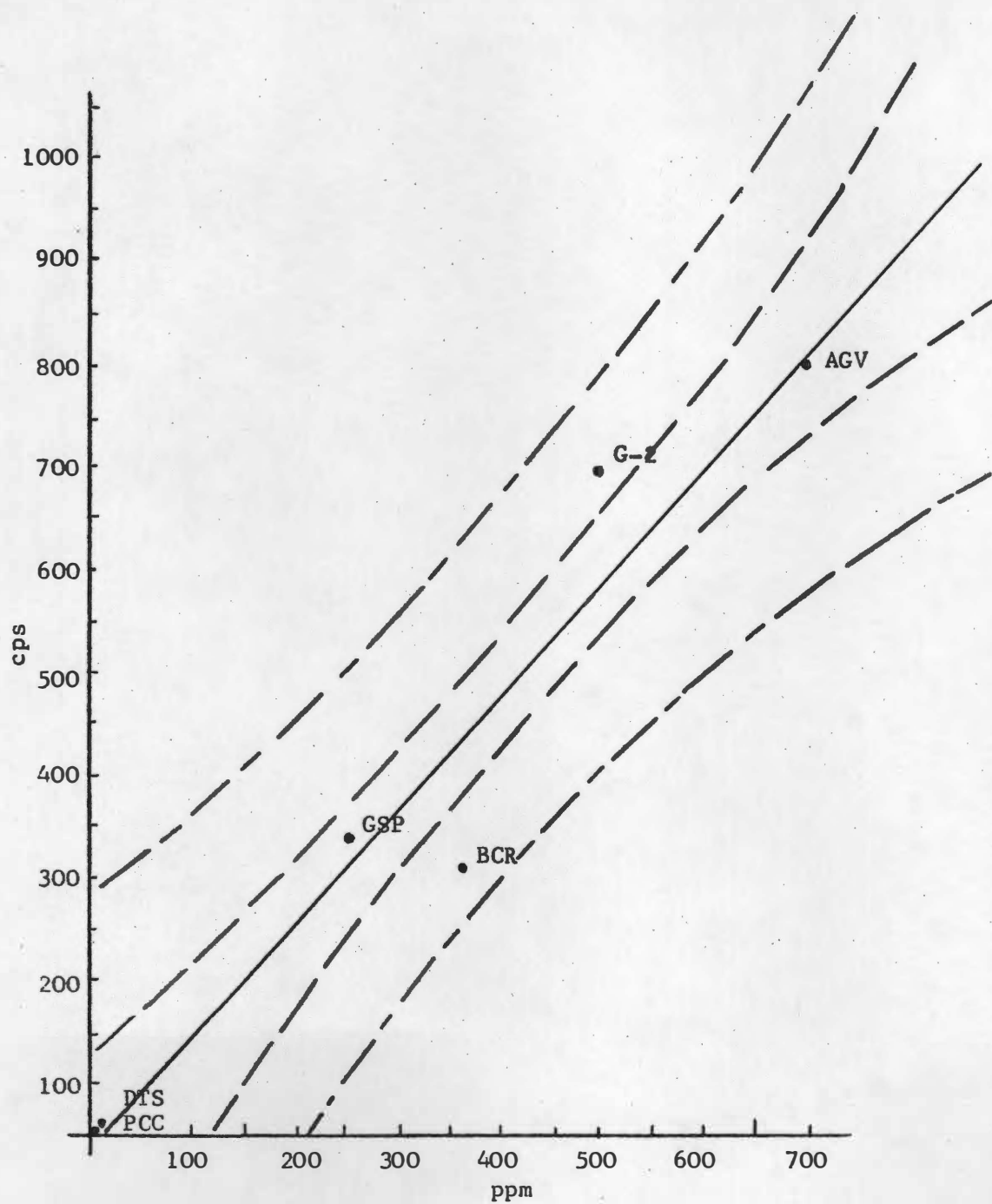


FIGURE 9. Correlation curve for strontium.

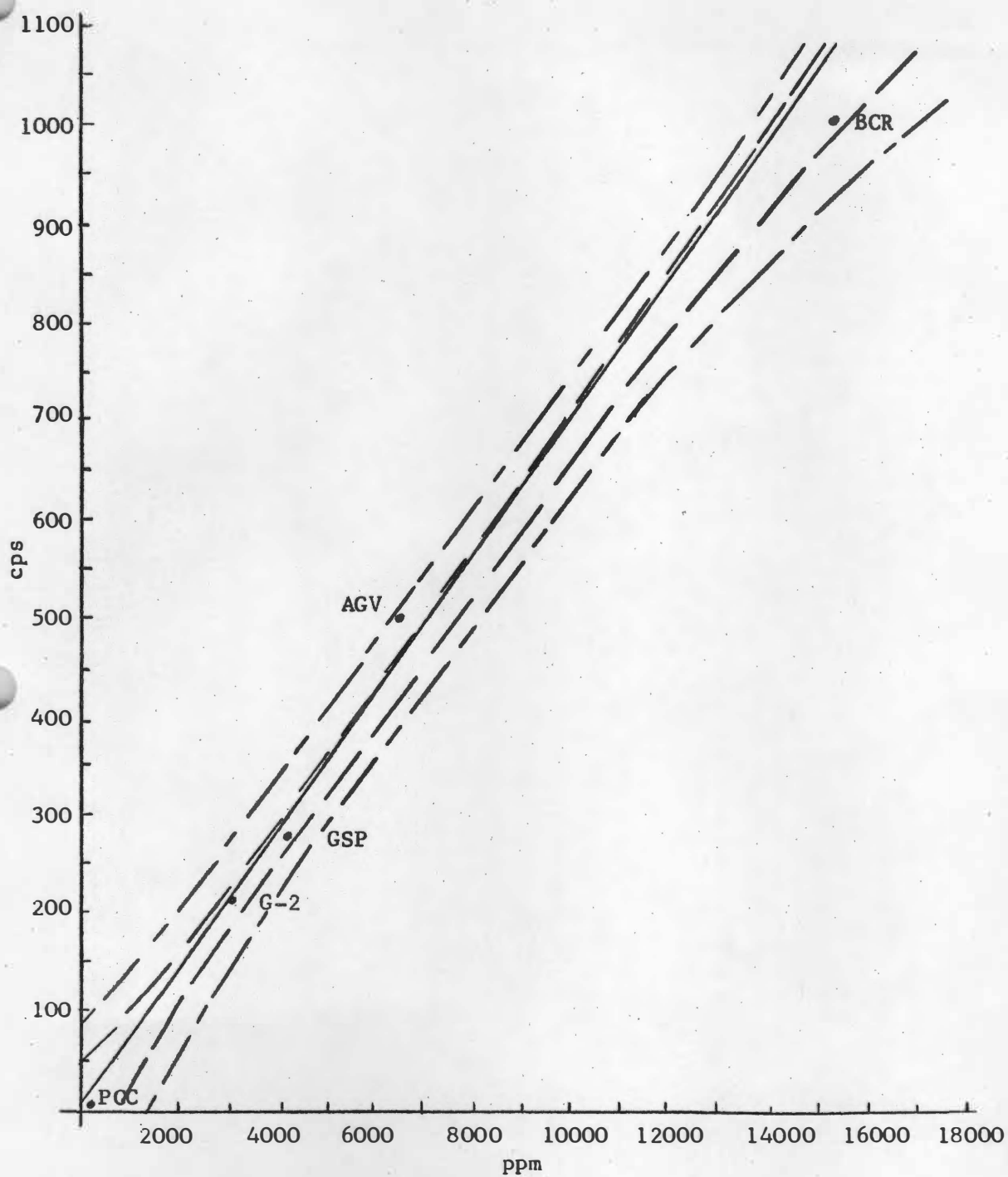


FIGURE 10. Correlation curve for titanium.

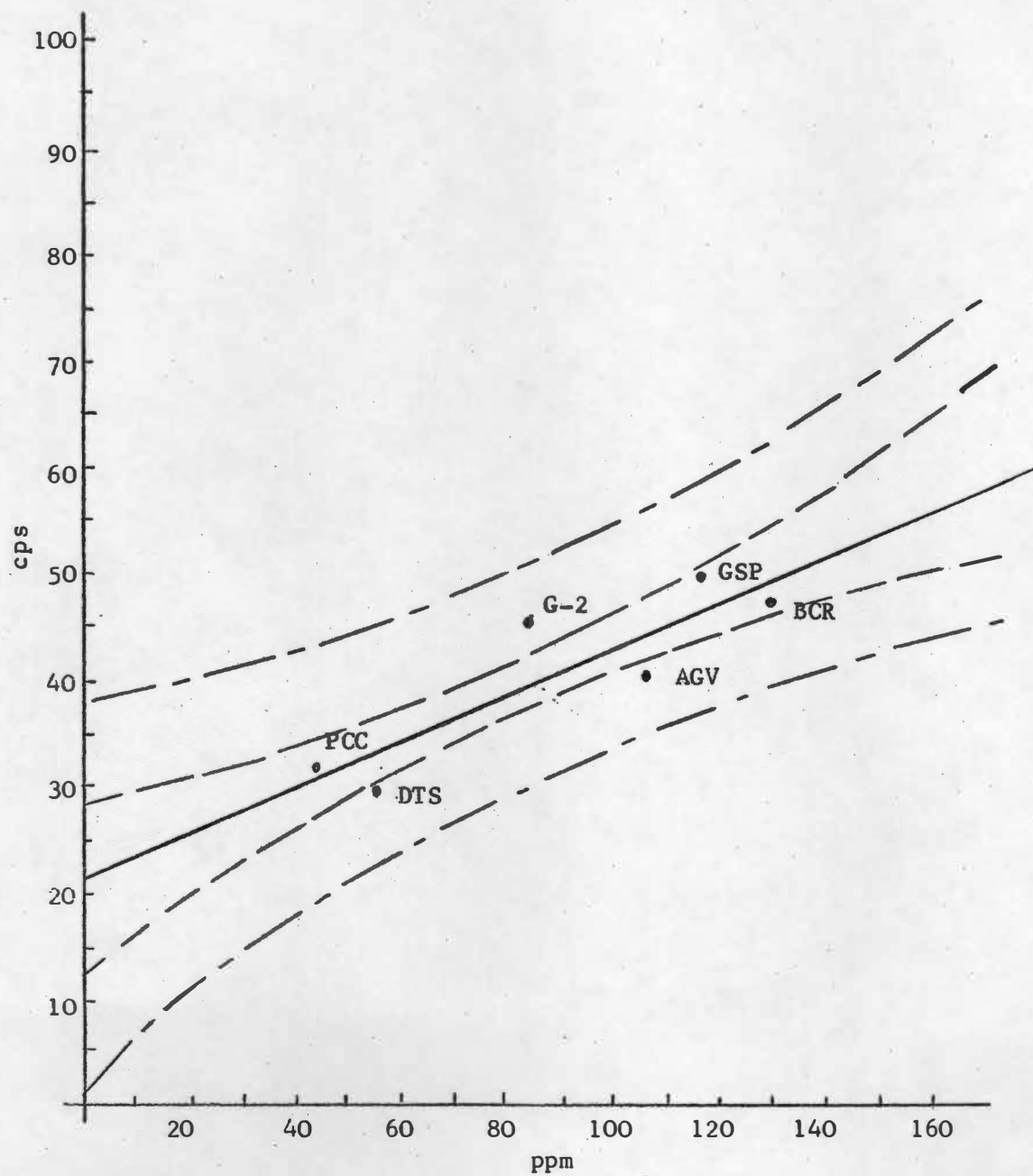


FIGURE 11. Correlation curve for zinc.

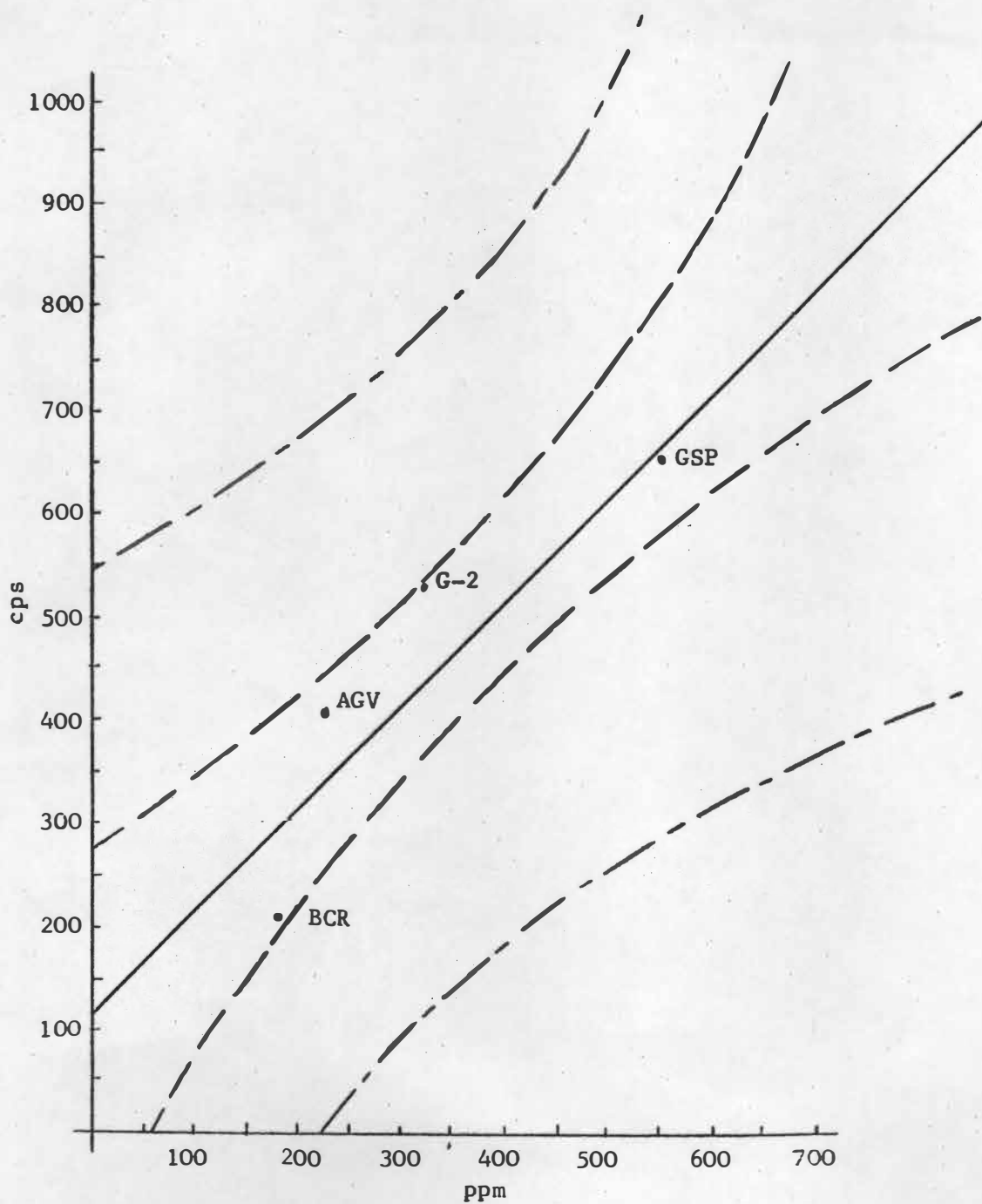


FIGURE 12. Correlation curve for zirconium.

APPENDIX C

DESCRIPTIONS OF DEPOSITS AND ARTIFACTS

Introduction

The descriptions of the soapstone deposits and artifacts which follow are based on X-ray diffraction and petrographic analysis. Each deposit was found to consist essentially of one of two mineral suites, the first consisting primarily of anthophyllite, talc, and chlorite, and the second composed of tremolite-actinolite, talc, and chlorite. Six of the deposits studied consist of the anthophyllite, talc, chlorite assemblage. They include the Leiceister #2, the Blue Rock Road, the Blue Rock, the Crabtree Creek, the Asbestos Mine, and the Asbestos Mine #2. The Shelton Mine, the Watermellon Branch, the Paceolet River, and the Hammett Grove deposits consist of the tremolite-actinolite, talc, and chlorite assemblage. Although there are essentially only two distinct mineral suites which comprise these deposits, the minerals of each deposit exhibits distinctive characteristics such as pleochroism, texture, the kind of accessory minerals present, and the relative mineral percentages which make up a deposit. In the descriptions which follow, the term porphyroblast is used in reference to grains which are distinctively larger than the other grains in the section and it does not imply a particular origin. Percentages given for each mineral (in volume percent) are based on visual estimates. Sizes and size ranges were measured using a calibrated eyepiece micrometer. The full extent of each deposit is not known since outcrops are scarce.

DESCRIPTIONS OF DEPOSITS

Leiceister #2

Leiceister #2 is a small deposit outcropping for approximately 40 feet along a road cut in Madison County, North Carolina. The deposit is composed of 70-80 percent talc, 5-10 percent anthophyllite, 5-10 percent biotite, 0-3 percent chlorite, 0-5 percent tremolite, and 1-2 percent magnetite. The sections contain porphyroblasts of anthophyllite and biotite in a matrix of fine-grained talc. A distinct lepidoblastic foliation is exhibited due to the linear arrangement of the biotite and anthophyllite (see Figure 13).

Talc occurs predominantly as a fine-grained mass with the grains generally less than 0.1 mm in size. However, a few larger flakes do occur and they appear to be pseudomorphs after anthophyllite. Anthophyllite occurs as long prismatic and irregularly-shaped grains up to 1.0 mm in length. Many are partially altered to talc. Overall they exhibit a nematoblastic texture. Biotite is present as tabular flakes up to 1.0 mm in diameter. The flakes are pleochroic, ranging from colorless to light brown. Although the majority of the flakes exhibit lepidoblastic texture, some occur as aggregates of randomly-oriented flakes.

Chlorite accounts for only 0-5 percent of the samples studied. It is present as tabular flakes exhibiting a colorless to light green pleochroism. It occurs most commonly as an alteration product of biotite. Magnetite is the dominant opaque mineral present. It occurs as euhedral to irregularly-shaped grains up to 1.0 mm in diameter. Iron oxide stains are common along fractures.

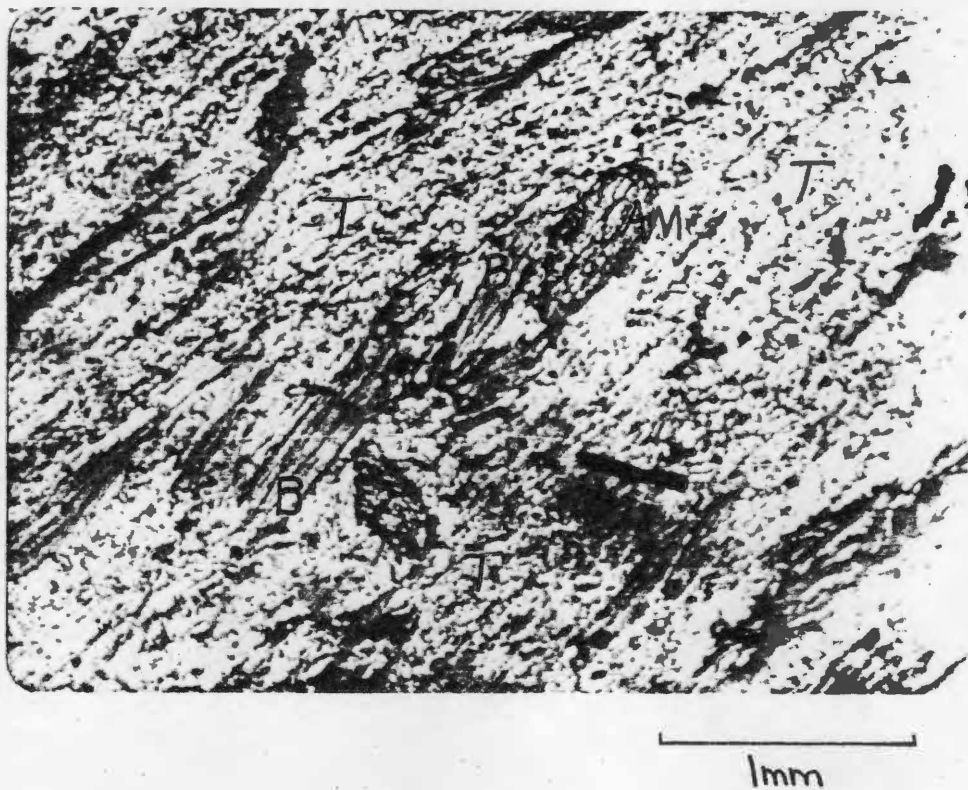


FIGURE 13. Lepidoblastic texture (parallel or subparallel alignment of biotite). B = biotite, Am = amphibole, T = talc. (Slide 1-m, plane polarized light.) Leiceister #2 deposit.

The Leiceister #2 deposit is distinguished from the other deposits studied on the basis of the occurrence of 5-10 percent biotite in its mineral assemblage. The Hammett Grove deposit is the only other deposit studied which contains appreciable amounts of biotite, but in the Hammett Grove deposit tremolite-actinolite is the dominant amphibole. The pronounced foliation and the fine-grained, massive nature of the talc are also distinctive characteristics for the Leiceister #2 deposit.

Blue Rock Road

The Blue Rock Road deposit occurs as a small hill approximately 50 feet in diameter which outcrops approximately 50 feet east of Blue Rock Road in Yancey County, North Carolina. The mineral assemblage consists of talc, chlorite, anthophyllite, magnetite, and hematite. The sections studied contained 75-90 percent talc, 5-15 percent chlorite, 0-5 percent anthophyllite, and approximately 1 percent magnetite and hematite. The texture is somewhat foliated, consisting of a matrix of talc with the other minerals distributed randomly throughout.

Talc occurs as tabular flakes up to 4.0 mm in diameter, some of which exhibit microfolds (Figure 14). Two varieties of chlorite are present. The dominant variety exhibits an anomalous blue birefringence which is characteristic of an iron-rich chlorite. The other type has a greenish-gray birefringence. The anomalous birefringent chlorite occurs as long, slender, grains, generally less than 1.0 mm in length. It is pleochroic ranging from colorless to pale green whereas the gray birefringent variety exhibits a stronger pleochroism, ranging from colorless to dark green. In several places the two types occur together and the

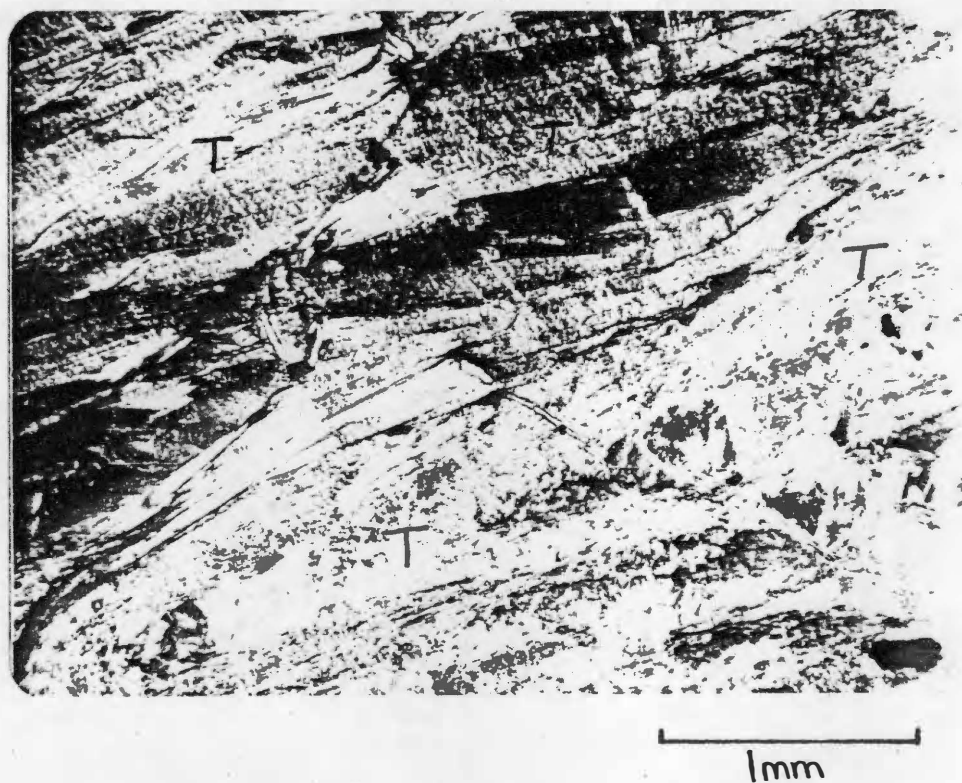


FIGURE 14. Large flakes of talc prevalent in the Blue Rock Road deposit. T = talc (Slide 4-N, crossed nicols).

anomalous birefringent chlorite appears to be replacing the other chlorite, and in places, talc (Figures 15 and 16).

Anthophyllite occurs as long prismatic grains and as fibrous aggregates up to 2.0 mm long. It ranges in abundance from only a trace in one sample to 10 percent in another. In most samples it is randomly oriented, but in one sample it shows a slight lineation giving the section a nematoblastic texture.

The accessory minerals include magnetite and hematite. Magnetite is present as euhedral and irregularly-shaped grains up to 1.0 mm in diameter. Hematite is commonly associated with magnetite and along fractures as a red powder and as red, translucent, anhedral grains.

The Blue Rock Road deposit is distinguished from the other deposits on the basis of the abundance of talc, and on the size and shape of the talc. Also distinctive is the occurrence of two varieties of chlorite, and the small percentage of amphibole present (generally less than 5 percent).

Blue Rock

The Blue Rock deposit is located approximately 1 mile north of the Blue Rock Road deposit. It occurs as a small outcrop and as numerous soapstone boulders along Blue Rock Road. It is composed predominantly of talc, chlorite, and anthophyllite. Talc comprises 50-60 percent of the deposit, chlorite 25-40 percent, anthophyllite 5-10 percent, magnetite 1 percent, and a trace of chromite and hematite. The dominant texture consists of grains and flakes of anthophyllite and chlorite set in a matrix of massive talc. The linear arrangement of the



FIGURE 15. Acicular form of chlorite. Also shows anomalous blue variety replacing gray birefringent chlorite. AC = anomalous chlorite, C = gray chlorite, T = talc. (Slide 4-S, crossed nicols.) Blue Rock Road deposit.

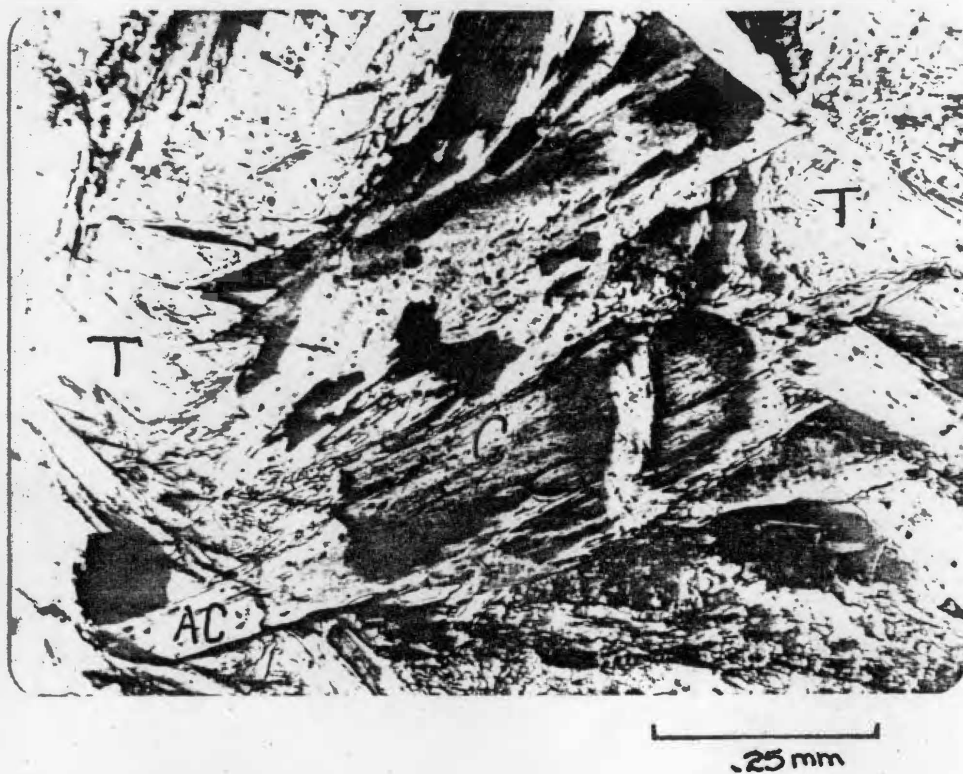


FIGURE 16. Anomalous blue chlorite replacing gray birefringent chlorite. AC = anomalous chlorite, C = gray birefringent chlorite, T = talc. (Slide 4-s, crossed nicols.) Blue Rock Road deposit.

anthophyllite gives the samples a nematoblastic texture.

Talc occurs as tabular flakes up to 1.0 mm in diameter and as a mass of fine-grained flakes, generally less than 0.1 mm in diameter. The fine-grained talc gives the sections a massive texture. No obvious lineation is exhibited by the talc. Two varieties of chlorite are present as in the Blue Rock Road deposit. However, unlike the Blue Rock Road deposit, the anomalous blue variety does not predominate. In this deposit the gray birefringent variety is the dominant chlorite. It occurs as randomly-oriented flakes up to 2.0 mm in diameter and displays a pleochroism ranging from colorless to pale green. Most occur as aggregates of flakes, many of which appear to contain relic fibers of anthophyllite. This relic anthophyllite is present as dark gray fibers in a black matrix when viewed under crossed nicols. The anomalous blue chlorite is always associated with the gray birefringent variety, appearing to grade into it. Anomalous blue pleochroism is characteristic of an iron-rich chlorite, such as penninite.

Anthophyllite occurs as acicular grains up to 2.0 mm in length. The grains are distributed in a linear fashion giving the sections a nematoblastic texture. Many of the grains are partially altered to talc and chlorite. Although most of the grains exhibit parallel extinction, a few grains display inclined extinction which is indicative of tremolite. A small tremolite peak was observed in the diffraction pattern of one of the samples.

Magnetite is the dominant opaque present. It occurs as euhedral and irregularly-shaped grains up to 1.0 mm in diameter. A few grains of chromite were also identified by powder camera analysis of the nonmagnetic

opaques; however, magnetite comprised the majority of the heavies. Hematite occurs as anhedral, red, translucent grains and as a fine-grained red powder.

Although this deposit has the same mineral assemblage and is located only a short distance from the Blue Rock Road deposit, there are some features which distinguish the two. Most distinctive is the differences in the chlorites of the two deposits. In the Blue Rock Road deposit the anomalous blue variety is the dominant chlorite, whereas in the Blue Rock deposit it is subordinate to the gray birefringent variety. Also, the chlorite in the Blue Rock deposit occurs in clusters or aggregates of flakes which gives the samples a green mottled or spotted appearance, whereas in the Blue Rock Road deposit the chlorite does not occur as aggregates but as individual flakes distributed throughout the samples. The percentages of the individual minerals present in each deposit also distinguishes the two deposits. All of the Blue Rock Road deposits contain at least 75 percent talc and as much as 90 percent in some samples. In the Blue Rock deposit the samples contain less than 75 percent talc, generally 50-60 percent. The Blue Rock Deposit contains up to 40 percent anthophyllite in some samples while the Blue Rock Road samples studied contain less than 10 percent anthophyllite.

Crabtree Creek

The Crabtree Creek deposit outcrops along East Fork Road and along Crabtree Creek over a distance of approximately 500 feet in southeastern Mitchell County, North Carolina. Besides outcropping along the creek and road, huge soapstone boulders occur strewn about the hillside east

of the road. The deposit consists of 70-80 percent talc, 10-20 percent anthophyllite, 10-15 percent chlorite, 1 percent magnetite, and a trace of hematite.

Talc occurs as randomly-oriented, tabular flakes up to 4.0 mm in length and 1.0 mm in width. Many of the flakes are bent and contain remnants of anthophyllite. Anthophyllite is present as long prismatic grains up to 2.0 mm long and as fibrous aggregates up to 4.0 mm long. The fibrous aggregates exhibit a light brown color, whereas the long prismatic grains are colorless. Most of the fibrous aggregates are partially altered to talc (Figure 17). The anthophyllite displays a nematoblastic texture giving the sections a distinct foliation.

Chlorite occurs as tabular flakes up to 1.0 mm in diameter and as aggregates of fine-grained flakes. Here, as in the Blue Rock Road and Blue Rock deposits, two varieties of chlorite are present, one with an anomalous blue birefringence and another with a gray birefringence. The majority of the chlorite exhibits gray birefringence, as in the Blue Rock deposit. Also, as in the Blue Rock deposit, some flakes exhibit both varieties. Chlorite is also found replacing anthophyllite.

Magnetite occurs as euhedral grains up to 1.0 mm in diameter. Hematite is present as red to yellow, translucent grains, generally less than 1.0 mm in diameter. Also, an iron oxide stain is present.

This deposit resembles the Blue Rock Road and the Blue Rock deposits in mineral composition in several ways, but it differs from them in texture and mineral characteristics. Like the Blue Rock Road deposit, the Crabtree Creek deposit contains large tabular flakes of talc up to 4.0 mm in diameter. However, unlike the Blue Rock Road deposit

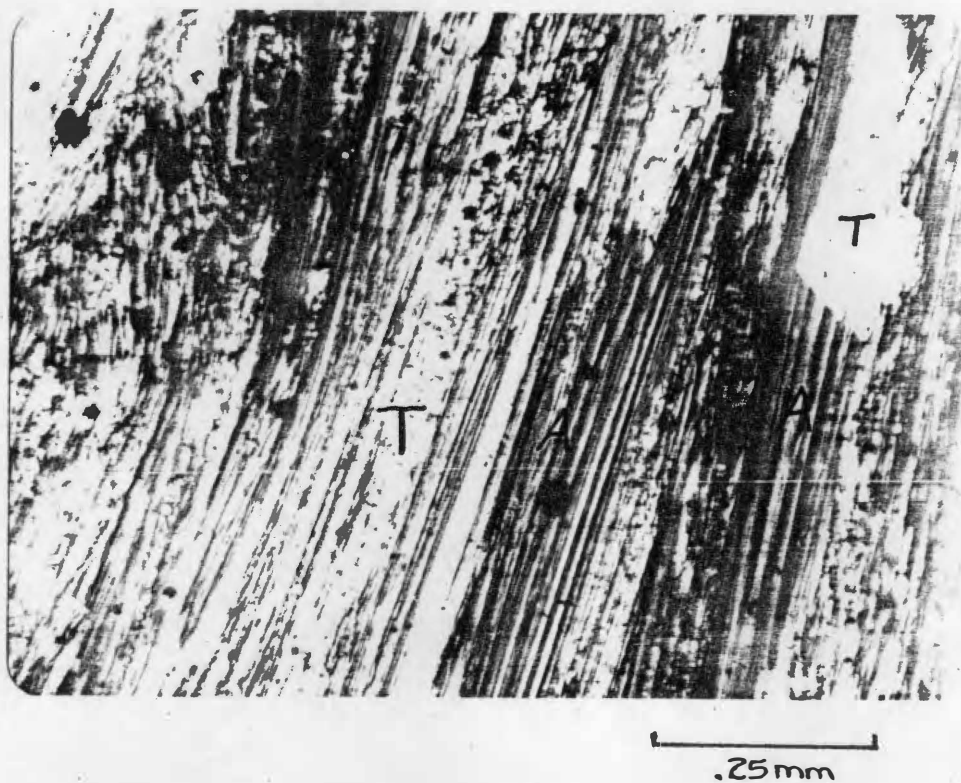


FIGURE 17. Fibrous anthophyllite partially replaced by talc.
A = anthophyllite, T = talc. (Slide 6-B, crossed nicols.)
Crabtree Creek deposit.

anthophyllite is more abundant in the Crabtree Creek deposit. Also, the anthophyllite occurs predominantly as fibrous aggregates, which are not present in the Blue Rock Road deposit. Unlike the Blue Rock Road deposit, chlorite occurs as aggregates of fan-shaped flakes which give the Crabtree Creek samples a spotted appearance (Figure 18). The Blue Rock deposit also contains aggregates of chlorite but the individual grains are not fan-shaped, as they are in the Crabtree Creek deposit.

Asbestos Mine

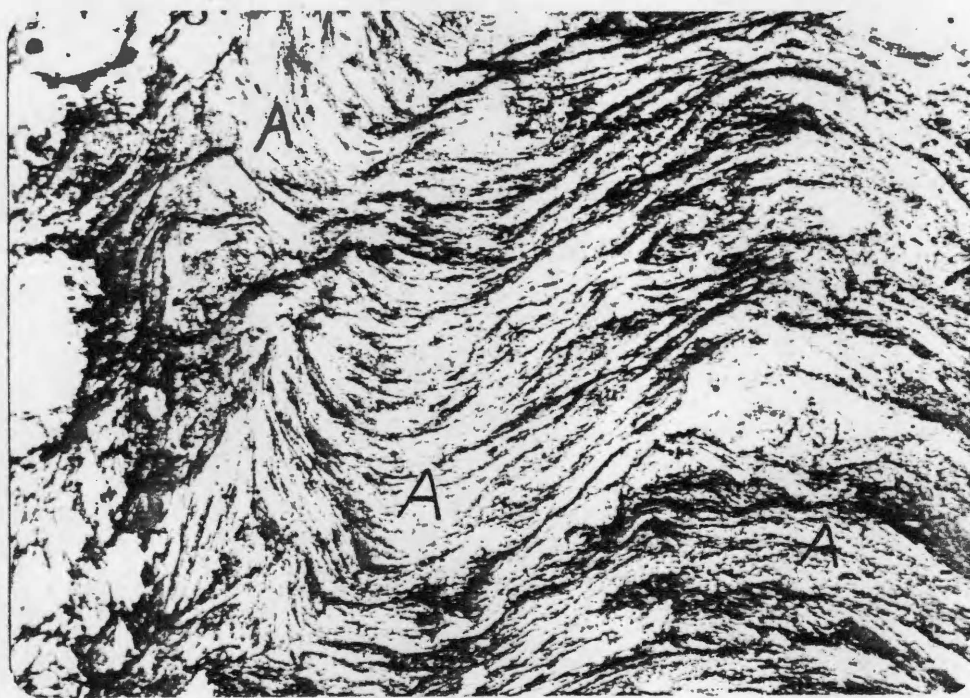
This deposit is located in northeastern Jackson County, North Carolina, approximately 200 feet southeast of Highway 64. Samples were collected from boulders of soapstone scattered about the area, which is approximately 150 feet in diameter. Due to recent construction in the area, it was difficult to tell if the boulders were in place. The samples studied exhibit a foliated texture and have a composition ranging from 40-80 percent talc, 10-50 percent anthophyllite, 5-10 chlorite, 1 percent magnetite, and a trace of hematite.

Talc is present as blade-shaped grains up to 5.0 mm long. Many appear to be pseudomorphs after anthophyllite. Overall, the talc displays a lepidoblastic texture. Anthophyllite is present as long, prismatic grains and as fibrous aggregates up to 4.0 mm in length. Most exhibit a linear arrangement, paralleling the talc lineation, giving the sections a nematoblastic texture. Microfolds are common in many of the fibrous aggregates (Figure 19), while many of the long, prismatic grains occur in radiating clusters. Much of the anthophyllite is partially altered to talc. Chlorite occurs as randomly-distributed grains, most



.25mm

FIGURE 18. Aggregate of fan-shaped chlorite flakes. C gray chlorite.
(Slide 6-B, crossed nicols.) Crabtree Creek deposit.



.25 mm

FIGURE 19. Fibrous anthophyllite exhibiting microfolds. A = anthophyllite. (Slide A.B., plane polarized light.) From Asbestos Mine deposit.

of which are pleochroic, ranging from colorless to pale green. The chlorite has a first order gray birefringence. No anomalous blue chlorite was observed.

Magnetite occurs as euhedral to irregularly-shaped grains up to 1.0 mm in diameter. Hematite occurs as red translucent grains less than 1.0 mm in diameter. Some of the samples have a reddish-brown color due to extensive iron oxide staining.

Asbestos Mine #2

The Asbestos Mine #2 deposit is in northeastern Jackson County, North Carolina, approximately 1/4 mile due east of the Asbestos Mine deposit. It occurs as a small soapstone hill approximately 25 feet in diameter outcropping along State Highway 64, just west of the Jackson County line. Like the Asbestos Mine deposit, this deposit consists of talc, anthophyllite, chlorite, and magnetite. However, anthophyllite is not as abundant in this deposit as it is in the Asbestos Mine deposit. Of the samples studied, talc comprises approximately 80-90 percent, anthophyllite, 5-10 percent, chlorite, 5-10 percent, and a trace of magnetite and hematite occurs.

Talc occurs as tabular and blade-shaped grains up to 3.0 mm in length. The talc is similar in form to that found in the Asbestos Mine deposit; however, the long, blade-shaped form is more prevalent in the Asbestos Mine samples than it is in the Asbestos Mine #2 samples. Also, like the Asbestos Mine deposit, anthophyllite occurs as long, prismatic grains and as fibrous aggregates, but the long, prismatic form is more abundant in the Asbestos Mine #2 deposit. These anthophyllite grains

are up to 4.0 mm in length, often occurring as radiating clusters. The anthophyllite displays a nematoblastic texture, but it isn't as pronounced as it is in the Asbestos Mine samples. Like the Asbestos Mine, much of the anthophyllite is partially altered to talc.

Chlorite occurs as tabular grains and as small, acicular grains, generally less than 0.5 mm in length. It occurs as colorless flakes, with no pleochroism, and exhibits a first order gray birefringence. The absence of color is characteristic of an iron-free chlorite, such as leuchtenbergite. The chlorite is usually associated with magnetite, occurring as grains surrounding the magnetite (Figure 20). The occurrence of an iron-free chlorite associated with magnetite may indicate that the physiochemical parameters at the time of formation were such that the chlorite gave up iron to form magnetite or that the chlorite is secondary forming as an alteration of another mineral. The texture supports the former premise. The magnetite occurs as randomly distributed euhedral grains up to 0.5 mm in diameter. Hematite is present as red translucent grains, less than 0.5 mm in diameter.

This deposit is similar to the Asbestos Mine deposit both in mineral assemblage and texture. However, it contains a greater percentage of talc than the Asbestos Mine deposit as well as containing lesser amounts of the fibrous anthophyllite. Overall, the two deposits are quite similar.

Watermellon Branch

Watermellon Branch is a small abandoned mine in Madison County, North Carolina, which extends back into a hillside. Soapstone outcrops

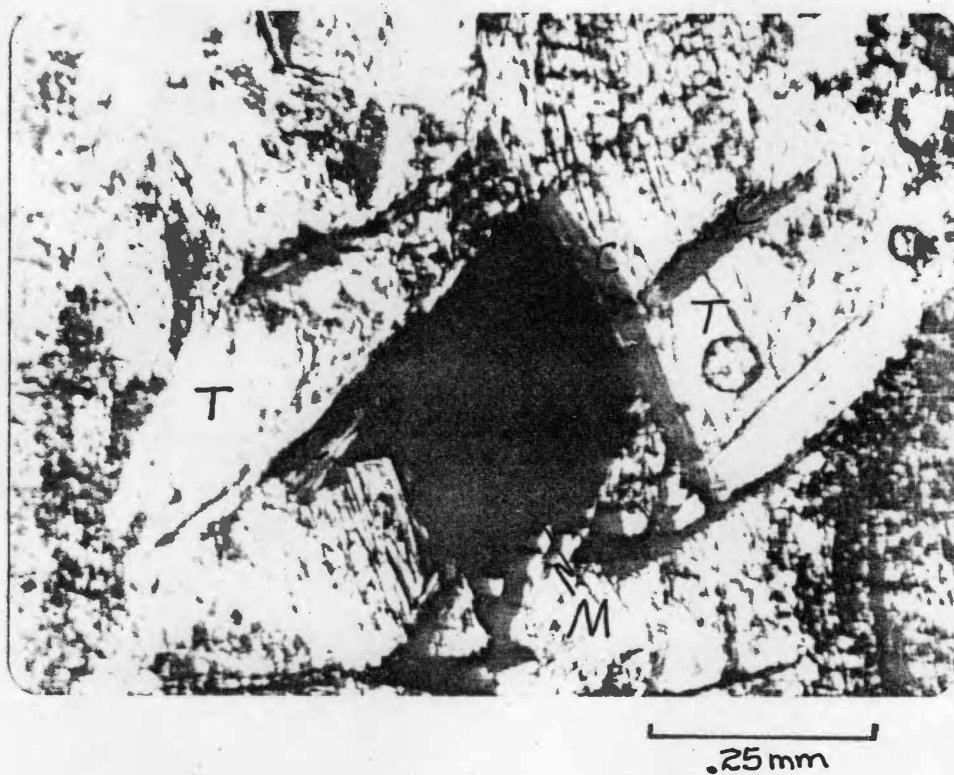


FIGURE 20. Chlorite concentrated around magnetite. C = gray chlorite, M = magnetite, T = talc. (Slide X-5, crossed nicols.) From Asbestos Mine #2 deposit.

for approximately 25 feet along the hillside on either side of the adit. Samples were taken from each side of the adit and from float lying near the entrance of the mine. Talc, chlorite, actinolite, magnetite, and rutile comprise the samples. Textural differences are great. Samples from the south side of the adit exhibit a strong foliation, due to the parallel arrangement of the amphibole in a matrix of talc and chlorite which exhibits a lepidoblastic texture. Samples from the north side of the adit show no foliation. The outcrop at this location isn't very extensive and it is difficult to say for certain but the textural and mineralogical differences from one side of the adit to the other may indicate that the adit was driven along a lithologic contact.

Talc ranges in abundance from 40-80 percent. It occurs as masses of fine-grained fibers, generally less than 0.1 mm in length. Tremolite-actinolite makes up from 5-50 percent of the samples studied. It occurs as small grains less than 0.1 mm long and as porphyroblasts up to 3.0 mm in length. The porphyroblasts are lath-shaped with an irregular outline, due to incipient alteration to talc. Although many grains are colorless, most exhibit a pale green pleochroism, characteristic of actinolite.

Chlorite makes up 10-20 percent of the samples, occurring as small flakes and as aggregates of flakes. The flakes range in size from 0.05 to 0.5 mm in diameter and exhibit a slight pleochroism ranging from colorless to pale green. They show radiating extinction due to the fan-shaped form of most of the flakes.

Magnetite and rutile are the dominant accessories comprising approximately 1 percent of the total samples. Magnetite is present as

euohedral to irregularly-shaped grains up to 0.5 mm in diameter. Rutile was identified in a polished section of the heavy minerals from a sample taken from the north side of the adit. No rutile was identified from the south side of the adit.

The occurrence of rutile in this deposit helps to distinguish it from the other deposits studied, since abundant rutile was not observed in the other deposits. Also notable is the variety in textures exhibited by this deposit. The samples from the north side of the adit contain about 50 percent tremolite-actinolite and exhibit no foliation, while the sample from the south side of the adit has only 5 percent tremolite-actinolite and displays strong foliation (Figures 21 and 22).

Shelton Mine

This deposit is an abandoned mine located in Madison County, North Carolina. Samples were collected from the mine dump and from outcrops of soapstone which occur about the area over a distance of approximately 100 yards. In these samples talc comprises from 50-80 percent, tremolite-actinolite approximately 10 percent, chlorite from 10-20 percent, magnetite 1 percent, and hematite a trace. Fluorapatite and rutile were identified in the heavy mineral analyses, both making up less than 1 percent of the heavies, which were dominantly magnetite. However, one sample contained approximately 20 percent fluorapatite. The texture ranges from very strong foliation in one sample to no foliation in another sample. However, most of the samples are foliated.

Talc occurs as a fibrous mass, with the grains generally less than 0.1 mm in length. Overall the talc gives the sections a

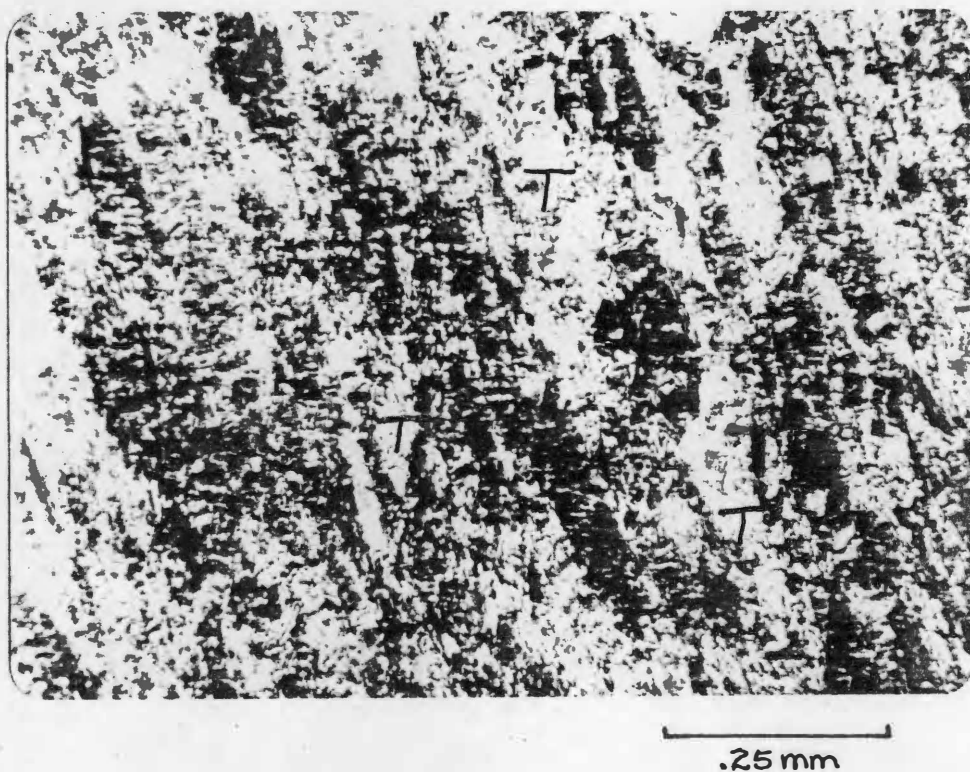


FIGURE 21. Lepidoblastic texture of massive talc. T = talc. (Slide 2-L, crossed nicols.) Watermellon Branch deposit.

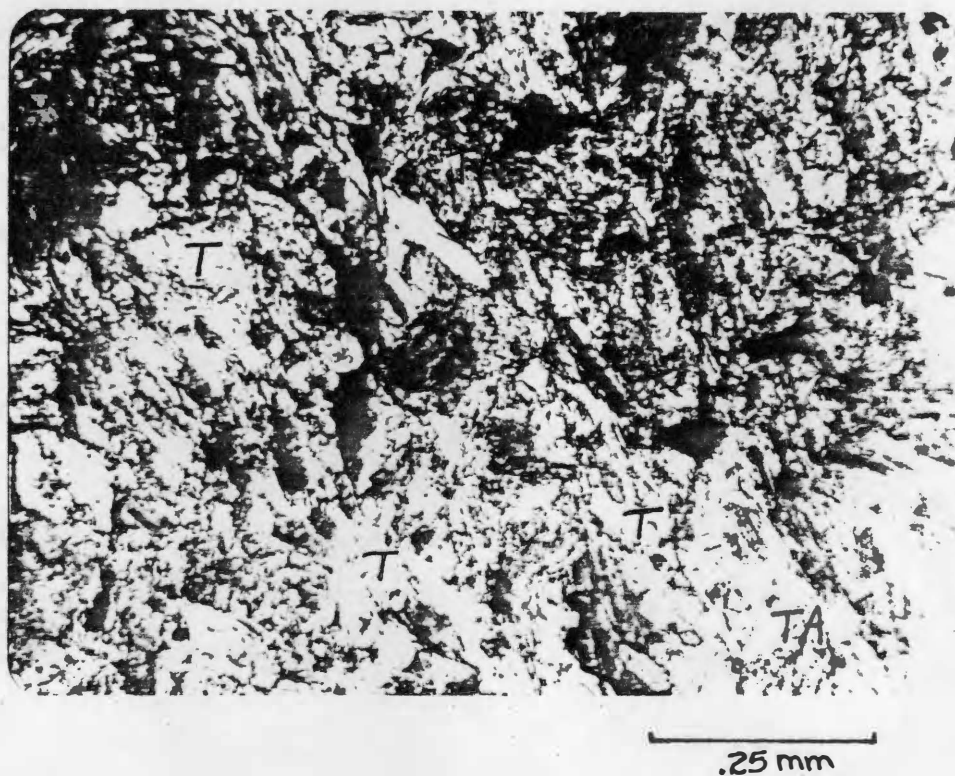


FIGURE 22. Randomly oriented tremolite-actinolite in fine-grained massive talc. TA = Tremolite-actinolite, T = talc. (Slide 2-R, crossed nicols.) Watermellon Branch.

lepidoblastic texture. Chlorite is present as small grains similar to the talc in form and as porphyroblasts up to 2.0 mm in diameter. The small grains exhibit a lepidoblastic texture, while the porphyroblasts display no preferred orientation. Many of the porphyroblasts exhibit small folds. The chlorite is pleochroic ranging from colorless to pale green and exhibits first order gray birefringence. Around the edges this gray birefringence often grades into an anomalous blue color. Most of the porphyroblasts are partially altered to talc (Figure 23).

Tremolite-actinolite occurs as prismatic grains up to 2.0 mm in length. Most of the grains are colorless, but some exhibit pale green pleochroism which is characteristic of actinolite. The degree of lineation displayed by the tremolite-actinolite differs from sample to sample. In some samples the lineation exhibits a strong nematoblastic texture which parallels the foliation of the talc. In other samples the tremolite-actinolite has a more random distribution, which masks the lepidoblastic texture of the talc and chlorite.

In one sample porphyroblasts of fluorapatite make up approximately 20 percent of the sample (Figure 24). Fluorapatite occurs as colorless, anhedral grains up to 1.0 mm in diameter. The grains exhibit a weak birefringence, ranging from isotropic to a first order gray.

This deposit is distinguished from the others on the basis of several characteristics. The occurrence of the large porphyroblasts of chlorite is quite distinctive because chlorite doesn't occur in this form in any of the other deposits. Also, the large grains of apatite present in one of the samples are unique for this deposit. The accessory minerals consisting of magnetite, rutile, and apatite, are also

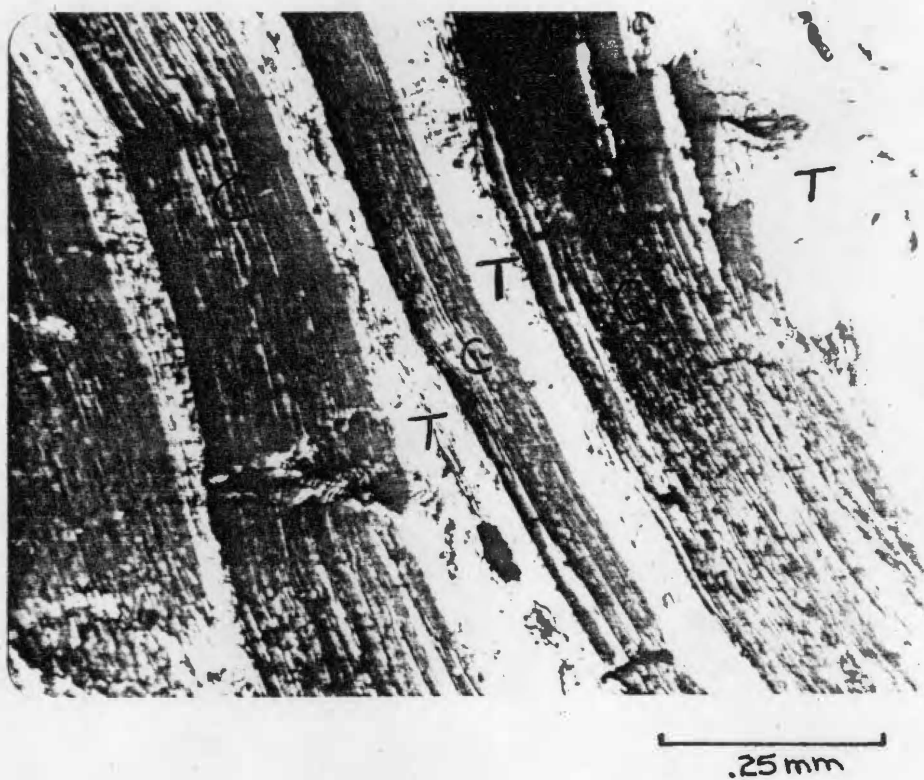


FIGURE 23. Chlorite porphyroblasts partially replaced by talc. Also displays microfolds. C = gray birefringent chlorite, T = talc. (Slide 3, crossed nicols.) From Shelton Mine deposit.

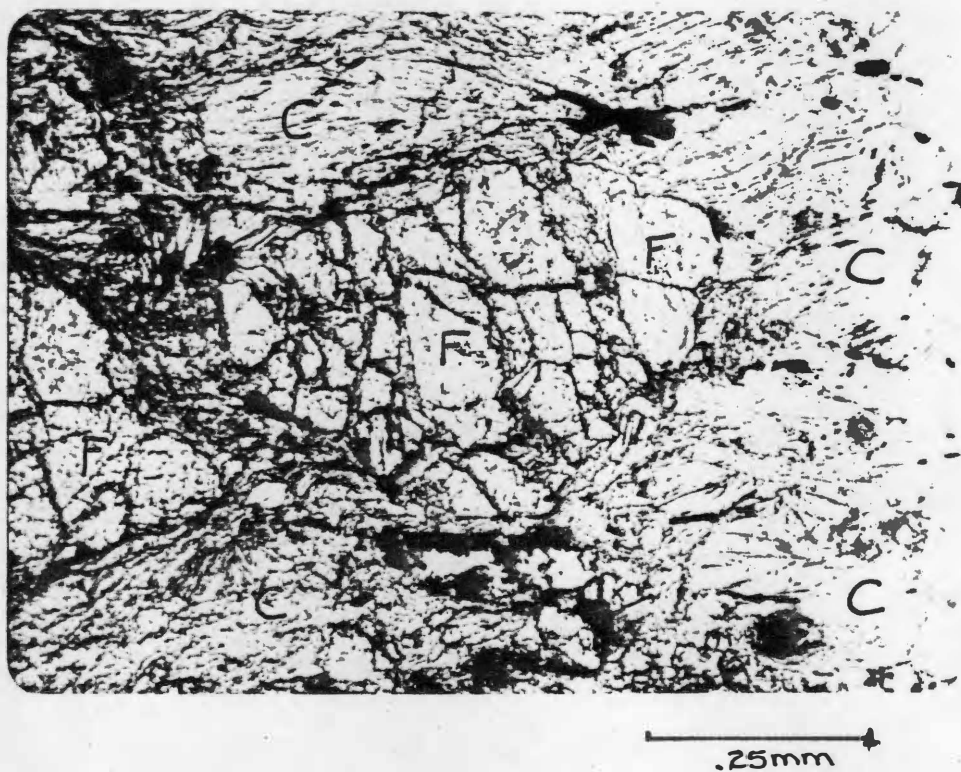


FIGURE 24. Porphyroblast of fluorapatite. F = fluorapatite, C = gray birefringent chlorite. (Slide 3-N, plane polarized light.) From Shelton Mine deposit.

distinctive for the Shelton Mine deposit.

Paceolet River

The Paceolet River deposit is in eastern Spartanburg County, South Carolina, approximately 10 miles east of Spartanburg. This deposit occurs as a soapstone hill approximately 300 feet in diameter. Samples were collected from soapstone boulders which cover the hill and form several outcrops. The deposit consists of talc, tremolite-actinolite, chlorite, biotite, magnetite, and hematite. In the samples studied, talc ranges in abundance from 30-85 percent, tremolite-actinolite from 5-60 percent, chlorite from 5-10 percent, biotite from 0-1 percent, magnetite 1 percent, and a trace of hematite.

Tremolite-actinolite occurs as prismatic grains up to 2.0 mm long and as fibrous aggregates (Figure 25) which often exhibit a radiating pattern. The fibrous variety resembles the fibrous anthophyllite of the Crabtree Creek deposit in form. Most of the long, prismatic grains are pleochroic ranging from colorless to light green. The tremolite-actinolite displays a nematoblastic texture.

Talc occurs as tabular flakes up to 2.0 mm in diameter. The size of the flakes appears to be related to the abundance of talc in each sample. The sample which contains more than 75 percent talc have large flakes, whereas the samples which contain less than 60 percent talc, possess flakes which are generally less than 0.5 mm in diameter. Much of this fine-grained talc is fibrous in form, giving the samples a massive appearance.

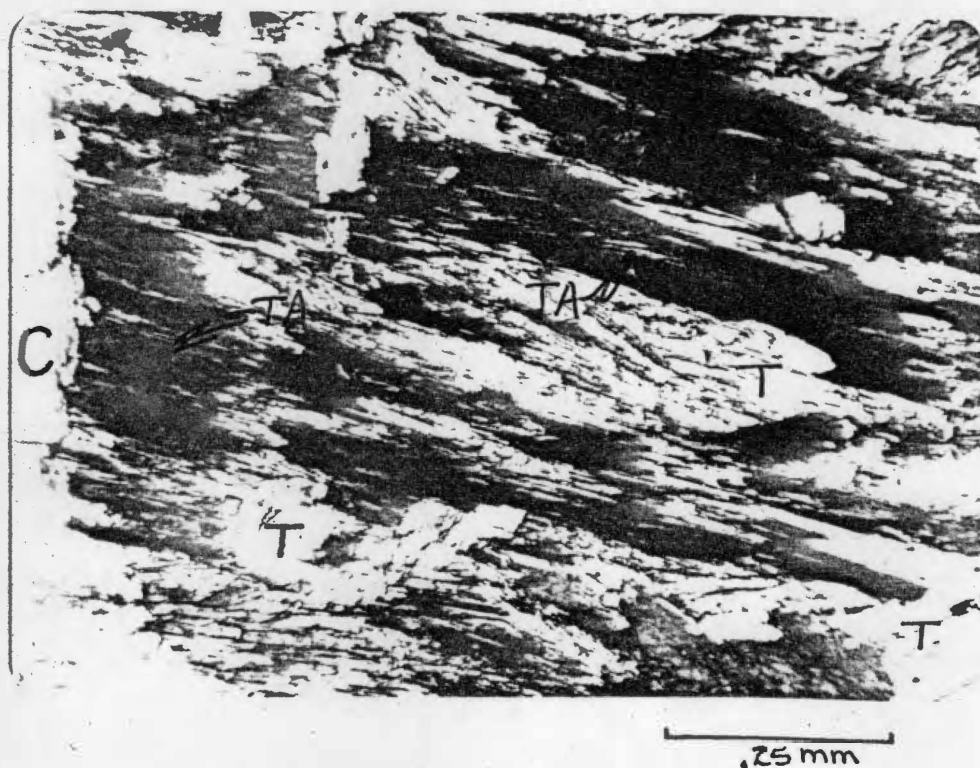


FIGURE 25. Prismatic grains of tremolite-actinolite partially replaced by talc. TA = tremolite-actinolite, T = talc, C = gray birefringent chlorite. (Slide P.R.-7, crossed nicols.) From Paceolet River deposit.

Chlorite occurs predominantly in prismatic grains up to 1.0 mm in length. The form resembles that of an amphibole, indicating that the chlorite is pseudomorphic after amphibole. The chlorite exhibits a light brown to green pleochroism and has a first order gray birefringence. Biotite is present in some of the samples as tabular flakes less than 0.5 mm in diameter. It is pleochroic, ranging from light brown to yellow.

Magnetite is the opaque present. It occurs as euhedral grains up to 1.5 mm in diameter. Hematite is present as a secondary mineral and is usually associated with magnetite.

Hammett Grove

The Hammett Grove deposit is in eastern Spartanburg County, South Carolina, approximately 1/2 mile N.65°E. of the Paceolet River site. The soapstone forms a gently sloping hill approximately 500 feet in diameter. This deposit is similar to the Paceolet River deposit in that it occurs as a soapstone hill with abundant soapstone boulders scattered about. Also similar to the Paceolet River deposit, the mineral assemblage consists of talc, tremolite-actinolite, chlorite, biotite, magnetite, and hematite. The samples from this deposit range in composition from 70-80 percent talc, 10-20 percent tremolite-actinolite, 0-10 percent chlorite, 0-10 percent biotite, 1 percent magnetite, and a trace of hematite. The dominant texture consists of porphyroblasts of tremolite-actinolite, biotite, and chlorite in a fine-grained matrix of massive talc.

Talc occurs as a randomly-oriented mass of grains, generally less than 0.1 mm in length. Although most of the grains are less than 0.1 mm long, some are up to 1.0 mm in length and appear to have replaced an amphibole. The tremolite-actinolite occurs as prismatic and lath-shaped grains up to 5.0 mm in length (Figure 26). Many of the grains exhibit a weak pleochroism ranging from colorless to light green. The tremolite-actinolite is distributed in a linear fashion giving the samples a nematoblastic texture.

Biotite is present as acicular grains up to 1.0 mm in length, exhibiting pleochroism ranging from yellow to dark brown. Many of the grains appear to be half biotite and half talc and they may be cross sections of interlayered talc and biotite flakes. However, the form resembles that of some of the amphibole twins with biotite occupying one twin and talc occupying the other (Figure 27). Biotite isn't present in all of the sections. Those sections which don't contain biotite contain chlorite. In these sections which contain chlorite, the chlorite occurs in the same form as the biotite has in the other sections. This may indicate that chlorite has replaced biotite in these sections. Also, biotite comprises approximately 10 percent of the samples in which it occurs. In the samples which contain no biotite, chlorite accounts for approximately 10 percent of the sections. The chlorite is pleochroic ranging from light brown to bluish green. Both biotite and chlorite exhibit a lepidoblastic texture.

Magnetite is present in all of the samples, accounting for approximately 1 percent of the samples. In one sample, H.G.-9, it makes up about 3 percent of the section. In this section it occurs

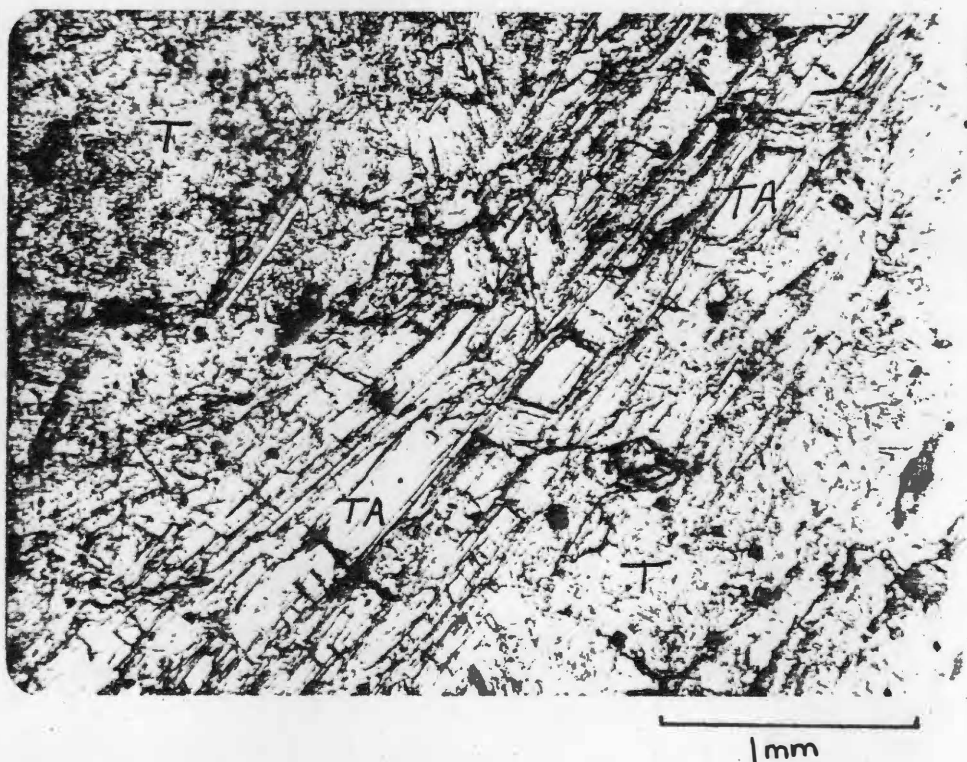


FIGURE 26. Tremolite-actinolite partially replaced by talc. TA = tremolite-actinolite, T = talc, B = biotite. (Slide H.G.-2, plane polarized light.) From Hammett Grove deposit.

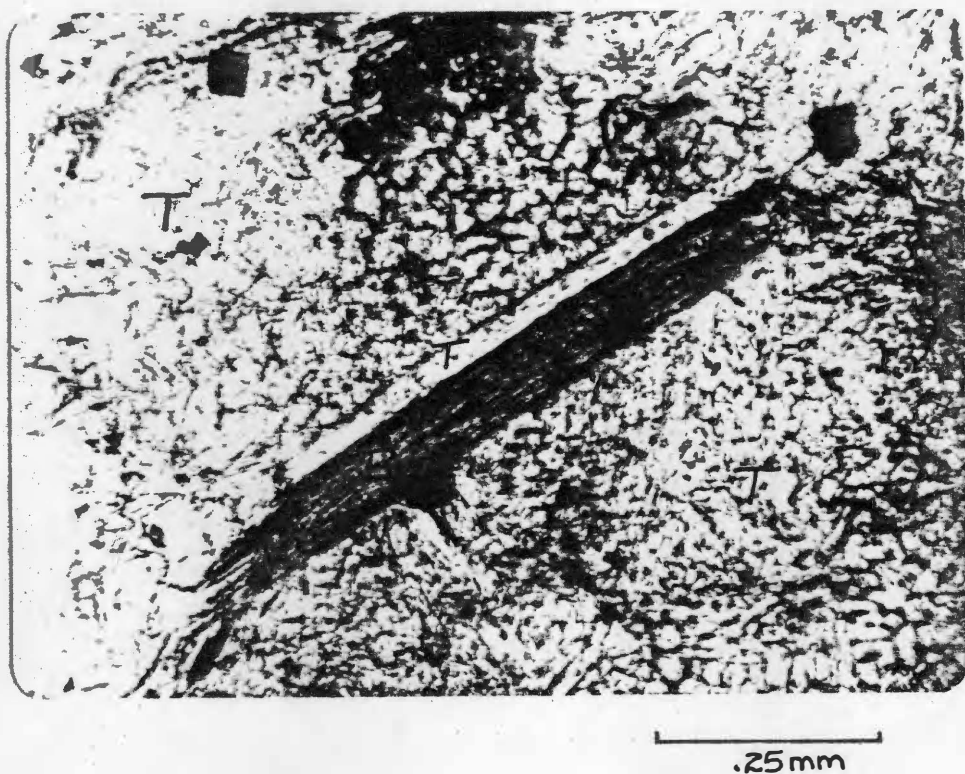


FIGURE 27. Porphyroblasts of biotite and talc in a talc matrix.
B = biotite, T = talc. (Slide H.G.-2, plane polarized
light.) From Hammett Grove deposit.

predominantly as euhedral grains up to 1.0 mm in diameter. The grains display a linear arrangement which could be relic flow structure.

This deposit resembles the Paceolet River deposit in some ways but several features distinguish the two. Most notable is the presence of biotite. Although one sample from the Paceolet River deposit contains a trace of biotite, the Hammett Grove deposit biotite comprises approximately 10 percent of several samples. Also, the talc in the Hammett Grove deposit occurs as much smaller grains and makes up a greater percentage of each sample than the talc in the Paceolet River samples. The Leiceister #2 deposit is the only other deposit studied which contains an appreciable amount of biotite. However, the biotite of the Hammett Grove deposit has a stronger pleochroism than the pleochroism exhibited by the Leiceister #2 biotite.

Descriptions of Artifacts--Hamilton County

Five artifacts from Hamilton County were studied in thin section and were found to exhibit two distinct mineral assemblages. One consists dominantly of talc, anthophyllite, and chlorite, the other consists of tremolite-actinolite, talc, and chlorite.

Two artifacts, III-376/7Hal and 29/21Ha20, consist of talc, anthophyllite, and chlorite. Both contain from 50-60 percent talc, 25-30 percent anthophyllite, 15-20 percent chlorite, 1 percent magnetite, and a trace of hematite. Also, a trace of rutile was identified in the heavies of III-376/7Hal. In these artifacts, talc is present as flakes up to 1.0 mm in diameter. Many of the flakes have the same form as some of the anthophyllite, which suggests that they are pseudomorphs after

anthophyllite. Anthophyllite occurs as randomly-oriented grains of various shapes. Most of the grains are long and prismatic in form, and often exhibit a radiating pattern. However, they also occur in fibrous aggregates and as lath-shaped grains up to 2.0 mm long. Most of the grains are partially altered to talc and chlorite. The chlorite occurs as small flakes, generally less than 0.5 mm in diameter. Most of the chlorite appears to be replacing anthophyllite. Magnetite is present as euhedral grains. Hematite is present as a fine-grained, red aggregate. The texture exhibited by these artifacts is essentially granoblastic in the sense that the grains are of similar size and there is no foliation.

Both artifacts exhibit the above characteristics. The only difference between the two is that sample 29/21Ha20 contains more fibrous anthophyllite than III-376/7Hal. Also, some of the chlorite flakes are larger in 29/21Ha20.

The other artifacts from Hamilton County, 158/65Hal0, 10/66Ha20, and 28/Ha27, exhibit the same texture as III-376/7Hal and 29/21Ha20. However, their mineralogy differs in that the amphibole in these artifacts is tremolite-actinolite rather than anthophyllite. Tremolite-actinolite is more abundant in these samples than anthophyllite is in the others. These artifacts contain 30-40 percent talc, 30-40 percent tremolite-actinolite, and 20-30 percent chlorite, with magnetite and hematite making up less than 1 percent of the sections. A trace of fluorapatite was identified in the heavy mineral analysis of 10/66Ha20, accounting for less than 1 percent of the heavies. Magnetite is the only opaque present.

Monroe County

Three artifacts from Monroe County were studied and were found to be quite similar to each other. The artifacts studied, 308/40Mr20, 137/40Mr21, and 166/40Mr25, are composed of 50-60 percent talc, 20-30 percent tremolite-actinolite, 20-30 percent chlorite, with magnetite, hematite, and apatite making up less than 1 percent of the sections. No distinct foliation is present.

Talc occurs as tabular flakes generally less than 1.0 mm in diameter. The chlorite occurs as tabular and fan-shaped grains up to 2.0 mm long exhibiting pleochroism, ranging from colorless to brownish-green. It also displays a first order gray birefringence. Most of the amphibole has a pale green color, indicative of actinolite. It occurs as broad prismatic grains up to 2.0 mm long. Many of the grains are partially altered to talc and chlorite. Some of the talc and chlorite appears to be pseudomorphic after tremolite-actinolite.

Cocke County

One artifact, F-12/40Ck11, from Cocke County was studied. It is comprised of approximately 80-85 percent talc, 15-20 percent chlorite, and 1 percent magnetite and hematite. No amphibole was observed, nor was any noted in the X-ray diffraction analysis. Lepidoblastic chlorite is distributed in a matrix of massive talc.

The talc is present as large flakes up to 2.0 mm across, some of which are bent. Although most of the flakes are lath-shaped in form, some are acicular, which resembles the form of chlorite. This may

indicate that this talc has replaced chlorite. The chlorite is also present as aggregates of flakes up to 2.0 mm in length. The chlorite is pleochroic, ranging from light brown to green and has a first order gray birefringence, which resembles the chlorite of the Monroe County artifacts. Magnetite occurs as euhedral and irregularly-shaped grains, generally less than 0.5 mm in diameter. Hematite is present as red, irregularly-shaped masses and as red, translucent grains.

Loudon County

One artifact, 144/40Ld24, from Loudon County, was analyzed. It consists of 60-65 percent talc, 35-40 percent chlorite, 1 percent magnetite, and a trace of hematite. No amphibole was observed, nor did X-ray diffraction data indicate its presence. However, some of the chlorite occurs as long prismatic grains similar to one of the common amphibole forms, indicating that it may be pseudomorphic after an amphibole. Also, some of these flakes exhibit a radiating pattern which is also common for the amphiboles.

The talc occurs in two distinctive forms, as lath-shaped flakes up to 1.0 mm in diameter, and as a mass of finer-grained talc, generally less than 0.5 mm in diameter. The chlorite also is present in two forms, acicular grains and lath-shaped flakes. The grains are generally less than 1.0 mm long and exhibit a pleochroism ranging from light brown to green. They have a first order gray birefringence, similar to the chlorite in the Cocke and Monroe County artifacts. The chlorite exhibits a lepidoblastic texture as does the Cocke County artifact. Magnetite is present as euhedral and anhedral grains up to 0.5 mm in diameter.

Jefferson County

Two artifacts, 432/1Je and 433/1Je, from the same site in Jefferson County were analyzed. Both samples are very similar in mineralogy and texture. The only difference is that 432/1Je contains approximately 3 percent anthophyllite, whereas no amphibole is present in 433/1Je. Both artifacts consist of approximately 80-85 percent talc, 15-20 percent chlorite, 1 percent magnetite and a trace of hematite. The samples are foliated with most of the talc and chlorite exhibiting a lepidoblastic texture.

Talc occurs as lath-shaped flakes which range up to 2.0 mm across, many of which are bent. Some of the talc has a long, prismatic form, similar to that of anthophyllite. Chlorite is present as lath-shaped flakes similar in form to the talc and as fan-shaped flakes up to 1.0 mm in diameter. Some of the large flakes exhibit incipient alteration to talc. The anthophyllite in 432/1Je occurs as prismatic grains up to 1.0 mm in length. Magnetite is present as euhedral and anhedral grains, generally less than 0.5 mm in diameter. Hematite occurs as red, translucent grains and as a stain.

Coffee County

Six artifacts from Coffee County were analyzed. Like the Hamilton County artifacts, the Coffee County artifacts exhibit two distinct mineralogies, one consisting of anthophyllite, talc, and chlorite, and another which is composed of tremolite-actinolite, talc, and chlorite.

Three of the artifacts contain anthophyllite. Artifact 59/40Cf34 consists of 45-55 percent talc, 30-40 percent anthophyllite, 5-10 percent ciotite, 2-4 percent chlorite, and 1 percent magnetite with a trace of hematite. The talc has a tabular form ranging from 0.5 to 1.0 mm in diameter. The anthophyllite occurs as lath-shaped and prismatic grains up to 2.0 mm in length. Much of it is partially altered to talc and biotite. The biotite flakes are generally less than 0.5 mm in diameter. The pleochroism ranging from light brown to yellow-orange in color.

Artifacts 61/40Cf34 and 185/Cf34 are very similar in mineralogy and texture. They consist of 75-85 percent talc, 5-10 percent anthophyllite, 2-5 percent chlorite, and 1 percent magnetite with a trace of hematite. The talc has the same form as the talc in 59/40Cf34, but in these two artifacts it is generally larger, up to 2.0 mm in diameter. Some of it also has an elongated form which is similar to anthophyllite, indicating that it is pseudomorphic after that mineral. Most of the anthophyllite is present as long, prismatic grains as in 59/40Cf34. However, unlike 59/40Cf34, some of the grains are larger, up to 4.0 mm in length. Most of the lath-shaped grains are partially altered to talc. The chlorite resembles the chlorite in 59/40Cf34. These two artifacts contain no biotite.

The other three Coffee County artifacts contain tremolite-actinolite rather than anthophyllite. They consist of 45-55 percent talc, 20-40 percent tremolite-actinolite, 20-30 percent chlorite, and 1 percent magnetite and hematite. Like the other Coffee County artifacts, there is no foliation. The talc resembles that found in the 59/40Cf34 sample. Tremolite-actinolite occurs as long, prismatic and

lath-shaped grains similar in form to anthophyllite in the other samples. It is pleochroic ranging from colorless to pale green. Like the anthophyllite, the lath-shaped tremolite-actinolite is partially altered to talc and chlorite. Chlorite occurs as tabular flakes up to 2.0 mm in diameter and exhibits a colorless to light green pleochroism.

Polk County

Two artifacts, 1008/2Pk1 and 115/2Pk1, from the same site in Polk County were studied. Both showed a high percentage of talc, 85-90 percent in 1008/2Pk1 and 75-80 percent in 115/2Pk1. Chlorite accounts for 10-15 percent of 1008/2Pk1 and 15-20 percent of 115/2Pk1. Both contain minor amounts of magnetite and hematite. A few grains of ilmenite were observed in the heavy mineral fraction of 115/2Pk1. The sections consist of porphyroblasts of chlorite in a matrix of fine-grained talc, with the chlorite displaying a lepidoblastic texture.

The talc occurs as small acicular grains generally less than 0.5 mm in length and as large tabular flakes up to 2.0 mm in diameter. These grains exhibit a massive texture. The massive variety is dominant in 115/2Pk1, whereas the large tabular flakes are dominant in 1008/2Pk1. Tremolite-actinolite occurs as prismatic grains up to 1.0 mm long. Many of the grains are partially altered to talc. Tremolite-actinolite makes up 2-5 percent of 115/2Pk1 but is absent from 1008/2Pk1. Chlorite makes up 0-15 percent of 1008/2Pk1 and 15-20 percent of 115/2Pk1. In 1008/2Pk1 the chlorite flakes are tabular and generally less than 0.5 mm in diameter. The chlorite is pleochroic from colorless to light green and has a first order gray birefringence. Magnetite and hematite

are the accessories with magnetite occurring as euhedral and anhedral grains up to 0.5 mm in diameter. A few grains of ilmenite were identified in the heavy minerals of 115/2Pk1.

These artifacts are similar to the Shelton Mine deposit both in texture and composition. However, these artifacts contain more talc than do the Shelton Mine samples.

VITA

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He is a member of the Geological Society of America, Society of Economic Geologist, Mineralogical Society of America, and Sigma Gamma Epsilon.