University of Richmond
UR Scholarship Repository

Master's Theses Student Research

4-1-1954

The distribution and ecology of the terrestrial shell-bearing mollusca of Hanover, Henrico, and Chesterfield counties, Virginia

John Bayard Burch

Follow this and additional works at: http://scholarship.richmond.edu/masters-theses

Recommended Citation
Burch, John Bayard, "The distribution and ecology of the terrestrial shell-bearing mollusca of Hanover, Henrico, and Chesterfield counties, Virginia" (1954). *Master's Theses.* Paper 90.

This Thesis is brought to you for free and open access by the Student Research at UR Scholarship Repository. It has been accepted for inclusion in Master's Theses by an authorized administrator of UR Scholarship Repository. For more information, please contact scholarshiprepository@richmond.edu.

Approved 5-29-54

Nolan E. Rice

J. C. Strickland

Jack D. Burns

Warwick R. West, Jr.

E. Sherman Grable

J. Stanton Pierce

THE DISTRIBUTION AND ECOLOGY OF THE

TERRESTRIAL SHELL-BEARING MOLLUSCA OF HANOVER,

HENRICO, AND CHESTERFIELD COUNTIES,

VIRGINIA

by

John Bayard Burch

LIBRARY
UNIVERSITY OF RICHMOND
VIRGINIA

A Thesis Presented to the Graduate School
of the University of Richmond in Partial Fulfillment
of the Requirements for the Degree of
Master of Science

University of Richmond

June, 1954

ACKNOWLEDGEMENTS

To the many individuals who have made the completion of this thesis possible, I wish to express my sincere appreciation. I am especially grateful to Dr. Nolan E. Rice, who directed the research, and to Dr. Robert F. Smart, for his help and assistance and in making possible my study at the University of Richmond. Grateful acknowledgement is also made to Dr. John C. Strickland for his invaluable advice and criticism, and to the other members of the staff to the Department of Biology for the many considerations they have shown.

It is a pleasure to acknowledge the aid of Dr. Henry A. Pilsbry, Curator of Mollusks, Academy of Natural Sciences of Philadelphia, Dr. J. P. E. Morrison, Associate Curator of Mollusks, U. S. National Museum, and Dr. Paul R. Burch, Professor of Biology (retired), Radford College, Virginia Polytechnic Institute, for the identification of certain critical species.

Acknowledgement is made to Dr. P. H. DeHart, Assistant Director, Dr. C. I. Rich, Associate Agronomist, and Mr. W. W. Lewis, Extension Agronomist, all of the Virginia Agricultural Experiment Station, Virginia Polytechnic Institute, and to Dr. Rodney C. Berry, Chief Chemist, Division of Chemistry, Department of Agriculture and Immigration, Richmond, Virginia, for analysis of and information concerning soil samples.

I am indebted to Dr. A. S. Pearse, Professor Emeritus, Department of Zoology, Duke University, for the bibliography of his paper (Pearse, 1953) on molluscan ecology presented at the 1953 Meeting of the Association of Southeastern Biologists.

Thanks are due to Professor Charles E. Packard, Associate Professor of Biology, Randolph-Macon College, Miss Katherine Putnam of Westhampton College, and Mr. Austin Somerville, Richmond College, for the addition of many specimens to my collections.

Grateful acknowledgement is made to Mr. Richard Collier and Dr. Alton D. Brashear, both of the Medical College of Virginia, and to Dr. Robert F. Smart and Mr. Samuel L. Cooke, of the University of Richmond, for their help in the photography of the specimens dealt with in this thesis.

I am particularly indebted to the Graduate School of the University of Richmond for a William's Fellowship and the Virginia Academy of Science for a Research Grant which helped meet the financial demands of this problem.

CONTENTS

Page

ACKNOWLEDGEMENTS.. II

INTRODUCTION.. 1

MATERIALS AND METHODS.. 2

DESCRIPTION OF THE AREA.. 4

DISTRIBUTION OF SPECIES.. 7

AN EVALUATION OF SOME ECOLOGICAL FACTORS RELATED TO THE OCCURRENCE AND DISTRIBUTION OF LAND SNAILS............. 18

- Habitat.. 18
- Plant Associations.. 19
- Organic Matter.. 21
- Inorganic Compounds.. 23
- Soil Type.. 27
- Moisture.. 28
- Hydrogen-Ion Concentration.. 29
- Climate.. 31
- Elevation.. 32
- Animal Associations and Predators................. 33

SUMMARY.. 34

LITERATURE CITED.. 36

APPENDIX.. 40

- A. Field Data Sheet.. 41
- B. Map of Hanover, Henrico, and Chesterfield Counties.. 45
- C. Geologic Map of Hanover, Henrico, and Chesterfield Counties..................... 45

D. Map of Collecting Stations with Elevations above Sea Level........................... 47

E. Key to Collecting Stations........................ 49

F. Map of Collecting Stations where Soil Analysis were Made................................ 53

G. Distribution Maps................................. 55

H. Frequency Indexes and Frequency Percentages....... 73

I. Plant Associations................................ 76

J. Snails Found at Stations where Soil Samples were Taken................................ 79

K. Frequency of Snails from Stations where Soil Samples were taken........................ 86

L. Table and Graphs of Frequencies of Snails in Relation to pH, Calcium, Magnesium, Phosphorus, Potassium, and Organic Matter.... 88

M. Plates and Figures of Land Snail Specimens........ 101

OGRAPHICAL SKETCH

INTRODUCTION

Very little has been published concerning the molluscan fauna of Virginia, this being also true for the area under consideration. A preliminary list of the Mollusca of Hanover County was published by J. B. Burch (1952) in which twenty-five species and subspecies of land snails were reported. Several of the land Mollusca of Henrico and Chesterfield Counties were listed by P. R. Burch (1950). These included the snails *Discus patulus* Deshayes, *Haplotrema concavum* (Say), *Mesodon thyroidus* (Say), *Stenotrema hirsutum* (Say), *Triodopsis Fallax* (Say), and *Ventridens* =(*Zonitoides*) *arboreus* (Say). Two additional species, *Helicodiscus parallelus* (Say) and *Retinella indentata* (Say), were reported by personal communication. *Triodopsis obsoleta* = (*Triodopsis hopetonensis obsoleta*) (Pilsbry) was reported by Hubricht (1953) as being an introduced form in Richmond but specimens have not been found in the present study. Pilsbry (1939-48) does not list any snails from the area dealt with here.

This thesis is concerned with the land snails of the Richmond area, including Hanover, Henrico, and Chesterfield Counties, Virginia, and centers around a study of their ecology and distribution.

MATERIALS AND METHODS

One hundred and seventy-eight collections from one hundred and twenty-three stations have been made throughout the area between June, 1952, and November 1953. Each station is listed by number in the table of Appendix E and on the distribution maps of Appendix G with reference to the nearest U. S. or State highway. To insure adequate coverage, county roadmaps and topographical quadrangle maps were utilized. All field data were recorded on special forms (Appendix A) in the field and placed in a permanent log-book.

Snails are not distributed evenly over any large area, but nearly always occur more commonly in certain situations than in others. In order to secure speciumens, the habitat preferences were first learned and then the snails were searched for in their preferred habitat.

Careful observations have shown that most of the land snails hide beneath decaying logs, leaf mold, rocks, and in general under any debris that offers adequate protection against desiccation and extreme temperature changes. The larger species were collected by simply turning over their protective covering and picking them off with forceps. Several forms were found beneath the bark of rotting logs.

A large number of the land snails of this region are minute in size (0.5 mm. - 2.0 mm.) and are, therefore, quite difficult to collect. The smaller species were obtained by running the leaf mold and top soil through a series of sifters, graduated from four meshes per inch to thirty meshes per inch. The residues were placed in shallow dishes and examined with a hand lens or compound microscope.

Specimens were killed in the field with seventy per cent ethyl alcohol and placed in shell vials, unless they were to be used for close study of external and internal anatomy. In this case they were brought into the laboratory, anesthetized in a five per cent chloretone solution and killed in ten per cent formalin. Measurements were taken by means of a vernier caliper or ocular micrometer, depending upon the size of the specimen.

Field observations show that land snails are not distributed at random. Because of this, random sampling methods were not used in studying their distribution, but random samples of soil were taken from the total number of stations in order to study the pH, organic and inorganic composition. At each station all the snails were taken from an arbitrarily selected nine square feet of habitat between May and September, 1953, the time of the year most favorable for collecting. A composite liter sample of soil, humus, and leaf mold was taken and sent to the Virginia Agricultural Experiment Station, Blacksburg, Virginia.

The pH values were obtained by a Hellige colorimenter as soon as the samples were brought in from the field. The analysis of the soil samples for organic matter and inorganic compounds was made by the Virginia Agricultural Experiment Station, Blacksburg, Virginia. The percentage of organic matter was determined by total combustion. The analysis of the soil samples in regard to inorganic compounds was recorded in pounds per acre of the compound (CaO, MgO, P_2O_5, K_2O) in terms of availability to plants. This is the amount extracted by a weak acid. A flame photometer was used for determination of potassium and a photolometer for calcium, magnesium, and phosphorus. The probable error in this method is about $\pm$ 5 per cent (Rich, 1954). All percentages were calculated from the above data.

DESCRIPTION OF THE AREA

The area under consideration is includes three counties in east-central Virginia, viz., Hanover, Henrico, and Chesterfield, covering an area of approximately 1179 square miles (Map I). The area is limited on the north by the North Anna and Pamunkey Rivers and on the south by the Appomattox River. The eastern boundary is for the most part marked by the Pamunkey, James, and Appomattox Rivers, and Matadequin and Turkey Island Creeks. The western boundary is in part formed by Tuckahoe and Skinquarter Creeks but the larger portion of it is not marked by a stream.

The area is bordered on the north by Spotsylvania, Caroline, and King William Counties, on the east by New Kent, Charles City, and Prince George Counties, on the south by Amelia and Dinwiddie Counties, and on the West by Louisa, Goochland, and Powhatan Counties.

Two physiographic regions, the Coastal Plain to the east and the Piedmont Plateau to the west, merge along a line which crosses each county, dividing Hanover and Henrico Counties roughly into equal halves and Chesterfield County into an area about four-fifths of which lies in the Piedmont Plateau. This fall zone is several miles wide, with no definite boundaries.

The Piedmont province is a region of hard rocks and rolling topography. The soils have been derived mainly from grantie and gneiss formations and comprise primarily the Durham and Cecil series (Bloomer, 1938). The Cecil series is the most widespread type of soil occuring over the Piedmont region. It is a gray, red, or brown loam with a red clay subsoil. What was formerly a plateau is now so deeply eroded by drainageways that little of the plateau surface remains. In its eastern part the Piedmont Plateau has an average altitude of about two hundred feet above sea level, but it rises gradually toward the west. Most of the streams which cross it flow through narrow valleys in rocky channels.

The Coastal Plain is a region of sand, clay, and other soft materials, laid down on an eastward-sloping floor of granite and other crystalline rocks and dips gradually to the east. The soils differ from those in the Piedmont in their loose structure, lack of loaminess, the predominance of sand, and the frequent occurrence of water worn gravel throughout the soil profile. For the most part, the Coastal Plain consists of a wide plateau trenched by broad, terraced valleys of numerous streams. The larger streams are tidal estuaries as far inland as the zone in which the hard rocks rise from under the deposits of the Coastal Plain and become high enough to cause rapids. As the rise of these rocks is usually fairly steep the stream valleys narrow in a short distance into rocky gorges which mark the change from the Coastal Plain to the Piedmont province.

The major portion of the two regions is well drained by several rivers and numerous tributaries. The most extensive drainage system is the James River which flows through the central part of the area, marking the boundary between Henrico and Chesterfield Counties. The largest tributary of the James in this area is the Appomattox River. The drainage system to the north consists primarily of the North Anna, Little, New Found, Pamunkey, Chichahominy, and South Anna Rivers.

The climate is generally mild with an average annual temperature of twelve degrees C. Because of a difference in elevation of almost three hundred feet, the average temperature of the region near the western boundary is slightly cooler than that of the district near the eastern boundary, however there is no apparent difference in the precipitation (Bennett and McLendon, 1906). The summers are long with only occasional, oppressive hot spells of short duration. The winters are not extremely cold and the snow fall is usually light, remaining on the ground only a short time. The annual precipitation averages about 43 inches (Latimer and Beck, 1913.) The wet months occur during the growing season in the spring and summer. The first killing frost comes usually about the first of November and the last severe frost is usually during the early part of April. (Bloomer, 1938).

DISTRIBUTION OF SPECIES

In this section an annotated list of species is given with notes on distribution. Complete taxonomy and description of these species may be found in any of the recent monographs on land snails (Pilsbry, 1939-48; Goodrich and van der Schalie, 1944; Baker, 1939; Goodrich, 1932; Walker, 1928). The classification followed here is that of Pilsbry.

Although no species in this area is abundant, i.e., "observed in numbers every time search is made for it in the proper habitat" (Dice, 1952), according to the scale of abundance commonly employed by ecologists, several species are common and generally distributed throughout the entire area. Several species have been found at only one station and may be introduced forms or epibiotics. Others are of frequent abundance and generally distributed and some are apparently restricted to a particular physiographic province.

Common species are arbitrarily defined as those found in sixty-five per cent or more of the total number of samples; numerous or frequent species in twenty-five to sixty-five per cent of the samples; occasional or scarce species in five to twenty-five per cent of the samples; and rare species in less than five per cent of the collections. Appendix H shows that two species are common, five frequent, fifteen occasional and twelve rare.

Subclass PULMONATA Cuvier
Order STYLOMMATOPHORA Schmidt
Suborder SIGMURETHRA Pilsbry
Family ENDODONTIDAE Pilsbry

Anguispira alternata angulata (Ferussac). Map V.

This species is of occasional occurrence and is generally distributed over the three counties. It has been found in greatest numbers in thickly forested river valleys and has been found associated with various oak and elm communities, being most abundant in oak-elm associations. It seems to be restricted to soils very high in calcium content and is most abundant at a pH range of 6.3-6.7.

Helicodiscus parallelus (Say). Map XI.[1]

This small, flattened, greenish-yellow snail is common throughout the area and, although associated with all the types of plant communities where collections were made, is prevalent in oak-pine stands. It is exceeded in abundance only by Zonitiodes arboreus (Say).

Punctum minutissimum (Lea). May XII.

This minute snail is rare and has been found in this area only in the Piedmont Plateau province, although P. R. Burch (1950,1952) has reported it in New Kent County, which borders Hanover County to the east, and in Norfolk County. It has been found associated with oak-elm and oak-pine communities, and only in the pH range of 6.3 - 6.7.

Family HAPLOTREMATIDAE Baker

Haplotrema concavum (Say) Map X.

Haplotrema concavum, generally considered a carnivorous species, is of frequent occurrence, being found wherever the habitat is favorable for other snails. Consequently, it has been found in a large

1. See Appendix M for figures.

number of plant communities, although more commonly associated with oaks, maples, and willows. Ingram (1941) considers this species an omnivore rather than a carnivore and in this case the plant association may have some direct influence on distribution.

Family POLYGYRIDAE Pilsbry

Mesodon appressus sculptior Chadwick. Map XI.

This form is of rare occurrence, being found only along the James River lowlands, primarily on the Chesterfield County side of the river. It has been found most frequently in willow and sycamore-willow communities and found associated only with soils very high in calcium content.

Mesodon thyroidus (Say). Map XII.

One of the larger land snails, *Mesodon thyroidus* is numerous in this area, being found most abundantly in the Piedmont, although P. R. Burch (1950, 1952) has found it in King William, New Kent, Elizabeth City, and James City Counties. Rehder (1949) found it "Common" at Virginia Beach, Princess Anne County. It is most generally associated with woodlands having a predominance of oaks.

Stenotrema hirsutum (Say). Map XV.

This is another species which seems to be generally restricted to the Piedmont, but has been found by P. R. Burch (1950, 1952) in New Kent and Elizabeth City Counties. It has an occasional occurrence in the Piedmont and has been found in two localities in the fall zone. The individuals found in Henrico and Chesterfield Counties comprise a small race, averaging somewhat less than 7 mm.

in diameter. Stenotrema hirsutum has been found in a number of oak and elm associations, most frequently in oak-pine associations. Although Lee (1952) states that in the vicinity of Ann Arbor, Michigan, S. hirsutum is restricted to river valleys and alkaline soils (pH range 7.5 - 8.5) this is not the case here. It is most frequent in woodlands some distance from streams and has been found only between pH values of 6.2 - 7.2.

Triodopsis albolabris (Say). Map XVIII.

Triodopsis albolabris is the largest land snail found in this region. It is more or less solitary, of occasional occurrence, and found in rather separated localities. It has been found only in associations with oak which is one of the dominant trees and most frequently in oak-maple communities.

Triodopsis fallax (Say). Map XVIII.

This scarce species is found in the Piedmont Province, except for one station near the fall zone in the Coastal Plain. However, P. R. Burch (1950, 1952) has found it in Charles City, New Kent, and James City Counties. Hubricht (1953) has reported it from York, New Kent, Sussex, Southampton, and Franklin Counties. It has been found most generally in edificarian communities.

Triodopsis hopetonensis (Shuttleworth). Map XIX.

Found in only one locality in Henrico County, near the James River (81) and in two localities in Chesterfield County (106 and 123). Hubricht (1953) states that it apparently does not occur north of the James River in Virginia. Its occurrence in Henrico may be due to accidental transportation, e.g., by birds (Oughton, 1948) or water (Powell, 1949).

Triodopsis obsoleta =(Triodopsis hopetonensis obsoleta) (Pilsbry) has been reported by Hubricht (1953) as an introduced form in Richmond, but specimens have not been found in this study. However, P. R. Burch (1952) believes that polygyrid forms with aperture dentation reduced or lacking are probably the result of a lack of sufficient calcium in the diet, since laboratory culture of snails in cultures deficient in food and calcium show reduced aperture dentation. Hubricht's T. obsoleta was probably T. hopetonensis. T. hopetonensis has been found in oak, sycamore-willow, and willow associations. These specimens were identified by P. R. Burch, Radford, Virginia.

Triodopsis tridentata juxtidens (Pilsbry). Map XIX.

Triodopsis tridentata juxtidens is of frequent occurrence and is generally distributed throughout the three counties. It is found predominantly in oak and elm communities, and at a pH range of 5.8 - 6.2, decreasing in number as the pH increases.

Family ZONITIDAE Pilsbry

Euconulus chersinus (Say). Map VII.

Found in a few, scattered localities in all three counties and in both physiographic provinces. It is associated commonly with a number of plant communities.

Euconulus fulvus (Müller). Map VII.

Although found in only one locality in this region (8), it has been reported by P. R. Burch (1950, 1952) from Charles City, Louisa, Spottsylvania, New Kent, and Goochland Counties.

Hawaiia minuscula (Binney). Map X.

This species, of occasional occurrence, is generally distributed throughout the area, and has been found most abundant in oak-sycamore communities and at a pH range of 6.3 - 6.7.

Retinella burringtoni (Pilsbry). Map XIII.

Found frequently in the Piedmont region, and usually in stands containing a large majority of oaks. It has rarely been found in the Coastal Plain. The southern-most point in its known range is at its type locality, Natural Bridge, Rockbridge County, Virginia (Pilsbry, 1946). This species was identified by J. P. E. Morrison, U. S. National Museum.

Retinella indentata (Say). Map XIV.

Retinella indentata is of frequent abundance and generally distributed over the entire area in association with a variety of trees. Its most common occurrence is in oak-poplar stands. *R. indentata paucilirata* (Morelet) was reported by J. B. Burch (1952) from Hanover County, but all specimens were probably atypical *R. indentata*. *R. indentata paucilirata* differs from the typical *R. indentata* mainly in a slightly larger umbilicus and somewhat greater size. However, some specimens from this area fit the description of *R. indentata paucilirata* very well, although J. P. E. Morrison indentified all specimens sent from Hanover and Henrico Counties as *R. indentata*. The form *R. indentata paucilirata* is a southern variety, Rehder (1949) giving its northern-most record in the coastal plain as along State Route 170, south of Moyock, Currituck County, North Carolina.

Retinella _rhoadsi_ _austrina_ Baker. Map XV.

Found only at two stations (88 and 103), both in the Piedmont of Chesterfield County in different plant associations, viz., sycamore-willow and oak-pine respectively. It has not been reported from any of the surrounding counties.

Striatura _milium_ (Morse). Map XV.

This minute species, one of the smallest found in this survey (diameter 1.5 mm., height 0.8 mm.) is found occasionally in small numbers. It is most frequent in oak, oak-pine, oak-poplar, and oak-sycamore associations. This is the only species in the area which is found in greater numbers in soil of .045 - .074 per cent calcium oxide.

Ventridens _ligera_ (Say). Map XX.

Ventridens _ligera_ is a large zonitid of occasional occurrence most common in the eastern James River flood plain. It most frequent occurrence is in association with oak-sycamore stands in the lowlands and in oak-pine stands in higher regions. Although Rehder (1949) states that it is apparently rare in the coastal region, but common at Virginia Beach, Princess Anne County, Hubricht (1953) has reported it from Southampton, Nansemond, and Elizabeth City Counties.

Ventridens suppressus magnidens Pilsbry. Map XX

This variety has been found occasionally throughout the area except for the Coastal Plain of Chesterfield County. It has been most frequently found in oak and oak-pine associations throughout the three counties, and at a pH range of 5.3 - 5.7. There seems to be a local race in Hanover County different from the forms found in the two counties to the south. This local race comprises individuals "in which the teeth diminish or even disappear in the fully adult stage (as they do in *V. suppressus*, typical form). Pilsbry (1954).

Zonitoides arboreus (Say). Map XXI.

This species is the most common land snail found in this vicinity in both number of specimens and distribution. It is not restricted to woodlands and is found in nearly all of the plant associations studied in this survey. However, it is of most frequent occurrence in associations predominating in oak. It is found in the most acid and the most alkaline soils, e.g., in the pH range 4.8 - 7.7, but most frequently at a range of pH 6.8 - 7.2.

Suborder HETERURETHRA Pilsbry
Family SUCCINEIDAE Pilsbry

Succinea aurea Lea. Map XVII.

Found only at three localities along the James River (65, 81, 113). This species was picked up from rocks near the waters edge.

Suborder ORTHURETHRA Pilsbry
Family CIONELLIDAE Kobelt

Cionella lubrica morseana Doherty. Map VI.

This species was found at only one locality, near the James River (85) in Chesterfield County. It was found under decaying oak, poplar, and sycamore leaves at the base of a granite cliff on soil with a pH of 6.0 and very high in calcium. It has been reported by P. R. Burch (1952) from Spottsylvania County.

Family PUPILLIDAE Turton

Columella edentula (Draparnaud). Map VI.

Columella edentula is a scarce, solitary species, but has been found in both physiographic provinces in all three counties. Of the neighboring counties it has been reported by P. R. Burch (1952) from King William. It has been found associated with oak-pine and maple-sweet gum stands.

Gastrocopta armifera (Say). Map VIII.

Found only at one station (26) in Hanover County, under and around a compost pile. It has been reported by P. R. Burch (1950, 1952) from Dinwiddie and Louisa Counties.

Gastrocopta contracta (Say). Map VIII.

Distributed over the entire area and of occasional occurrence. It is most abundant in oak and oak-poplar associations and at a pH range of 6.8 - 7.2. Found rarely in soils with less than very high calcium content.

Gastrocopta pentodon (Say). Map IX.

Gastrocopta pentodon in this region is rare and apparently restricted to the Piedmont region. However, it is reported in the Coastal Plain from Elizabeth City County (Burch, 1950). It has only been found in plant associations abundant in oak. This species was identified by Henry A. Pilsbry, Academy of Natural Science of Philadelphia.

Gastrocopta procera mcclungi (Hanna and Johnson). Map IX.

Gastrocopta procera mcclungi is also rare and found at only three localities in the western Piedmont of Hanover County (3,8,12). It has been found in New Kent County by P. R. Burch (1952).

Pupoides albilabris (Adams). Map XIII.

This is a rare species which has been found in two localities (9, 27) in the Piedmont of Hanover County and one locality (70) from the Coastal Plain of Henrico County. It has been reported by P. R. Burch (1950, 1952) in Louisa, Spottsylvania, King William, and Dinwiddie Counties. In Hanover and Henrico Counties it has been found associated only with oak-maple stands.

Vertigo Ovata (Say). Map XXI.

Found at several stations in the Piedmont region associated with oak-maple and oak-poplar stands. Although not found in the Coastal Plain of the area, it has been reported from Norfolk County (P. R. Burch, 1950).

Family STROBILOPSIDAE Jooss

Strobilops aenea (Pilsbry). Map XVI.

Occurring frequently and generally distributed over the entire area. This minute, dome-shaped species was found most commonly under the bark of fallen oak trees. When found in the humus it was most frequent at a pH range of 6.3 -6.7 and soil of very high calcium content.

Strobilops labyrinthica (Say). Map XVI.

This species, very similar to *Strobilops aenea*, is not restricted to any particular region, but is scarce. It has been reported by P. R. Burch (1952) from Louisa, King William, and New Kent Counties.

Family VALLONIDAE Pilsbry

Vallonia excentrica (Sterki). Map XVII.

Vallonia excentrica is a rare species found only in the Piedmont of Hanover and Henrico Counties. It has been reported from the Coastal Plain of Virginia by P. R. Burch (1950) in Norfolk County. It was found at a pH of 7.5 at the only station where soil analysis data are available for this species.

Order BASOMMATOPHORA Schmidt
Family CARYCHIIDAE Leach

Carychium exiguum (Say). Map V.

This minute species, one of the smallest in the area (length, 1.6 mm.; width, 0.7 mm.) has been found occasionally in the Piedmont, associated only with stands where oaks are abundant. It has been reported by P. R. Burch (1952) from New Kent County.

AN EVALUATION OF SOME ECOLOGICAL FACTORS RELATED TO THE OCCURRENCE AND DISTRIBUTION OF LAND SNAILS OF HANOVER, HENRICO, AND CHESTERFIELD COUNTIES

The relative importance of the factors which may influence the distribution and occurrence of land snails in this area has been determined by inference from an analysis of statistical data, by observations in the field, and from the literature. Consideration is given in the following sections to habitat, plant associations, organic matter, inorganic compounds, i.e., calcium (CaO), magnesium (MgO), potassium (K_2O), and phosphorous (P_2O_5), soil type, water, hydrogen-ion concentration, climate, elevation, and animal associations and predators.

Habitat

Land snails may be found almost everywhere, even in comparatively dry habitats that would seem unfavorable for animal life, and in comparatively wet regions, as swamps and marshes. In general, species that can live in the most unfavorable places also occur in the most favorable. It is recognized by ecologists that abundance is of great importance in determining the most favorable habitat of an animal. Many snails, as their abundance indicates, are associated with distinctive kinds of habitat, being more frequent in certain situations than in others. To illustrate, *Succinea aurea* Lea has only been found in very moist places, generally near bodies of water; *Strobilops aenea* (Pilsbry) is found most commonly under the bark of decaying oak logs; *Triodopsis fallax* (Say) has been most frequent under debris around buildings and in urbanized areas. In general, snails in this area are most common under and around decaying deciduous logs in damp, forested stream valleys. Although isolated woodlands in the midst of cultivated areas often afford favorable snail habitats, the same species in greater abundance can generally be found in a nearby river valley. This is probably correlated with the amount of moisture present and the greater protection from wind and its drying effect. Jacot (1935) found that all species in dry open-field woodlands in North Carolina (as compared to those of moist cove woodlands) have low spires and suggests that this is due to the better protection provided by low spires in that outer whorls protect the inner whorls into which the snail retires during dry periods. Therefore, there is apparently a direct correlation between the drought resistance of a species and its occurrence in a more extreme habitat.

Plant Associations

There is a close relationship between land mollusks and forest types. Shimek (1930) states that this relationship is so close in the Mississippi Valley that each serves as an index to the other. However, the region studied here does not give sufficient evidence to warrant a conclusion on the basis of floral ranges. Although evidence, as given by the distribution of several species in this area, shows that some are restricted to the Piedmont region and not found in the Coastal Plain, many of these species have been reported to occur by other authors (P. R. Burch, 1950; 1952; Hubricht, 1953;

Rehder, 1949) further east. However, the fact that fewer species, and specimens of widely distributed species, are generally found in the Coastal Plain region is probably correlated with the greater predominance of coniferous trees, the sandier soil, and the less favorable river valley habitats of the Coastal Plain. Similar distribution of snails was found by Rensch (1930) on islands of the Dutch East Indies, where the number of species of snails was greater inland, increasing with the altitude, moisture, vegetation, and favorable substrate.

It has long been observed that land snails are virtually absent from pure stands of coniferous trees, being prominent only in deciduous forests, although Savely (1939) found Polygyra =(Mesodon) thyriodus (Say) occasional, Euconulus chersinus (Say)common and Zonitoides arboreus (Say) common in and under pine logs in the Duke Forest. Van der Schalie (1939) found a rich molluscan fauna in a coniferous area in Delta County, Michigan. However, the area was in a limestone region and he concluded that "apparently, in limestone areas the vegetation may vary without materially affecting the molluscan life."

In the present investigation, land snails were found so rarely in pure stands of pine that for the most part it was considered impractical to search for them there. However, it was observed that land snails are most abundant in oak-pine stands (Appendix I) but generally associated only with the oaks. The abundance of snails in oak-pine communities may be explained on the basis that natural mixtures between trees producing a poor humus layer (e.g., pine) and trees producing a good humus layer (e.g., maple) tend to improve the structure and consistency of the humus layer (Diebold, 1935). Archer (1939), studying molluscan ecology in southern Michigan, found the greatest number of species of land snails in oak-hickory communities. Jacot (1935), in studying the molluscan populations of the plant associations of old growth forests and rewooded fields in the asheville Basin of North Carolina, found the greatest number of specimens in an old growth hardwood forest. He found the next greatest abundance of specimens in a yellow pine-oak community.

Baker (1939) states that the majority of the species of land mollusks in Illinois are associated more commonly with "oak, maple, willow, and other deciduous trees." This is also the case in Hanover, Henrico, and Chesterfield Counties where by far the greater number of snails were found around oak logs in stands of broad leaved trees, predominantly oak. Where snails are associated with particular plant communities it does not mean that they feed on the plants, or necessarily on the humus, but the conditions of soil and climate favorable to these trees may also be the conditions favoring the snails. A definite plant association cannot be assigned as a limiting factor in snail distribution for snails do not always comform to plant formations, as has been pointed out by Boycott (1929).

Organic Matter

The fungal hyphae of decaying wood and leaves in most instances provide most of the food for land snails. To a lesser extent, larger fleshy fungi and green plants are used for food. Haplotrema concavum (Say), which is probably mostly carnivorous in its food preferences, was observed to be an exception.

There are differences in opinion as to the effect of available food on the distribution of land snails. Boycott (1929, 1936) states that food is not a factor in snail distribution in Britain. Oughton (1948) says that "food, other that lime, is not restrictive" to snail distribution in Ontario. He suggests that changes in the plant community affect snails only insofar as they modify water and lime potentialities. Shimek (1930) is of the opinion that the habits and distribution of land snails are chiefly determined by food requirements and moisture. Strandine (1937,1938) found a moderate correlation between calcium (CaO) and snail distribution in the Chicago area and a correlation between fluctuations of calcium and organic materials in the soil. He asserted that snail distribution could not be explained by a single environmental factor (i.e., calcium) and is probably the result of the interaction of several factors. Jacot (1940) observed that the abundance of the soil fauna varies with the amount of available organic matter, chiefly plant material. Strandine (1941) found that Succinea ovalis populations increased in the spring and early summer when the available leaf mold was greatest.

It has been found in this area that the distribution of snails has a very high correlation with the amount of organic material present in the soil (Appendix L, Graphs 51 and 52). Very few snails are found associated with soils of less than three per cent total organic matter, a standard considered very high for plant nutrition. This would indicate that land snail distribution is at least partially restricted by the amount of organic matter present, although this may not be entirely due to organic food requirements. Organic matter is not only important in supplying food and chemical compounds for snails and nutriment for the plants they live on, but also largely controls the moisture retaining capacity of the soil.

The amount of organic matter present is to a large degree a function of organic-matter-forming material per unit area. Although the quantity of organic matter in forest soils is less than that of grassland soils (Nikiforoff, 1938; Dice, 1952) the greater abundance of snails in forests is probably due to cover, less extreme changes in temperature, and higher calcium content of the humus. Grasses have a relatively low content of calcium (Pierre and Allaway, 1941).

The amount and type of organic matter in the soil may be correlated with the various plant associations, hence the general preference of snails for certain plant associations may readily be seen. Since the bulk of organic resudues in every soil is furnished by plants, "the general character of vegetation will be a major factor in determining the quantity, distribution, and general quality of soil organic matter, including humus" (Nikiforoff, 1938).

Inorganic Compounds

Calcium. Mollusks are intimately dependent upon a lime supply for the construction of their shells which contain large amounts of calcium carbonate. The correlation between lime supply and abundance of land snail shells is close enough that collectors have long recognized the presence of limestone in the form of cliffs and outcrops as particularly favorable collecting stations. Van Cleave(1951) has pointed out that accumulations of recent or fossil shells represent stored supplies of lime, and may be used as indicators for soil suitable for plant cultivation. Experiments by Oldham (1929, 1934) on land snails, and Bevelander and Benzer (1948) on marine mollusks, have shown that weight of the shell and the amount of calcium formed in the shell is directly correlated with the available supply of calcium. Reichert (1927), experimenting on the reactions of snails to various factors, found that when the substrata agree in physical and mechanical factors, the presence of lime-salts may produce positive reactions, and when the substrata are similar in lime content, physical, mechanical, and optical factors may call for a positive tropism. Brockmeier (1929), observing land snails in nature, and in captivity, found that snails are able to detect carbonate of lime and dissolve it by an extended application of the ventral surface of the foot.

Clapp (1895, 1900), Clench (1930), Boycott (1934), Burkill (1944) Oughton (1948), have observed land snails rasping at the shells of other individuals and have inferred that snails may obtain some of the lime necessary for shell production by eating discarded mollusk shells. My observations on snails cultured in the laboratory at the University of Richmond showed that the rasping of shells invariably occurs in cultures poor in soil calcium. This never occurs in cultures to which calcium carbonate has been added. After the shell has been completely formed, i.e., in cultures containing only adult specimens, rasping still occurs in the absence of available calcium but to a marked lesser extent. Strandine (1938) found under laboratory conditions that young snails did better on soil enriched with calcium carborate, but older snails apparently did equally well on unenriched soil or sand.

Calcium is essential for snail growth and metabolism, being required for both normal body metabolism and in construction of the protective limy shell. Robertson (1941) states that calcium per se may be the important factor in mollusk distribution. Oughton (1948) and Boycott (1929,1936) infer from the distribution and abundance of snails on calcareous soils derived from rocks rich in lime, that the sole nutritional factor limiting the distribution of different species of land snails is the availability of calcium. Strandine (1937, 1938) analyzed soil in studying the distribution of forest snails in the Chicago area and found a "moderate correlation" between replaceable calcium in the soil and snail distribution, but believed snail distribution could not be explained by such a single environmental influence. It has been found by analysis of the soil in the area included in Hanover, Henrico, and Chesterfield Counties that there is a marked correlation between land snail distribution and the amount of calcium in the leaf mold and soil (Appendix L, Graphs 12 and 13). No specimens were found at stations having less than 0.019 per cent total available calcium. Very few were found between 0.010 and 0.044 per cent available calcium, and relatively few between 0.045 and 0.074 per cent. These are values which are generally considered low, medium, and high for plant nutritional requirements. The majority of our species and specimens are found where the humus and soil has an available calcium content over 0.075 per cent. This would indicate that, although many of the snail species here are not restricted to soil of very high calcium content, they either prefer it or occur in greater abundance in its presence.

Therefore, calcium is an important factor in limiting the occurrence and distribution of land snails, although not the only one.

Probably the most important factors in limiting land snails to hardwood forests are the lime present in the leaves, the relatively thicker humus layer, and the smaller amount of leaching. The leaffall of trees such as beech, birch, and oak is relatively rich in lime as compared to pine leaffall (Perry, 1928). Fenton (1941) states that the most marked difference between the soils developed under coniferous and deciduous forest trees is the distribution of the organic matter and the amount of leaching of the soil beneath. Under coniferous trees the humus layer is thin, relatively acid, and the underlying soil is greatly leached. Nafziger (1940), in analyzing soil samples from hardwood plots treated ten years previously with calcium carbonate, found that most of the lime remained in the upper 15 cm. of soil, i.e., very little leaching had occurred.

<u>Other Inorganic Compounds</u>. Chemicals in the soil other than calcium may limit the distribution of land snails. Magnesium is known to be an important constituent of the shells of marine mollusks. (Clarke and Wheeler, 1922). It was found in the area studied here that the number of snails increased as the magnesium in the soil increased (Appendix L, Graphs 21 and 22). Although the correlation for magnesium and number of species and specimens of snails was not quite as marked as for calcium, a definite correlation exists. No snails were obtained from soils where the available magnesium content was less than 0.00 3 per cent for plant nutrition.

The number of snails also increases as the concentration of potassium (K_2O) in the soil and leaf mold increases (Appendix L, Graphs 41 and 42). The number of snails reaches a maximum at a phosphorous (P_2O_5) concentration of 0.002 - 0.004 per cent, and then declines for higher concentrations (Appendix L, Graphs 30 and 31). The effect of these compounds on snail distribution is obscure.

Soil Type

Very little work has been done on soil type other than "calcareous" and "non-calcareous" soils as correlated with molluscan distribution. Dowdy (1944) in studying the invertebrates of three soil types, viz., medium fine sandy loam, silty clay loam, and gravelly clay, found the most snails in silty clay loam and none in medium fine sandy loam. J. B. Burch (1952) in studying the land mollusca of Hanover County found seven soil types represented by the collections, the most common being meadow, Norfolk sandy loam, and Leonardtown loam. Strandine (1938) found under laboratory conditions snails did better on sand than on soil, but older snails did equally well on sand, loam, or calcium enriched soil. Diebold (1935) found soil characteristics more important than the species of forest tree in the development of the type of humus layer. Indirectly, then, it would seem in this case that soil type would partially restrict the distribution of land snails.

No attempt was made in this survey to determine soil type since soil analysis was made by the Virginia Agricultural Experiment Station, Virginia Polytechnic Institute, and it is not as yet possible to determine soil types from soil samples (Rich, 1953). Recent soil maps of Hanover, Henrico, and Chesterfield Counties are not available.

Moisture

Water, in regard to both function and to bulk, is one of the most important constituents of living matter. There is a very close correlation between relative intensities of biological pressure and the amounts of available moisture, provided other conditions, such as the supply of mineral nutrients and temperature, remain relatively constant (Nikiforoff, 1938). It has long been understood by conchologists that land snails are very dependent on an available supply of moisture. Contradictions may seem evident here, in that some snails are known to live through considerable periods of drought. However, Oughton (1948) observed that several species of snails surviving long periods of drought died upon coming in contact with an available supply of water. He suggests that similar conditions may occur in nature.

Strandine (1938) states that "there is some correlation between the rate of evaporation and the density of the snail population" in the Chicago area. Strandine (1941) found that fluctuations in the density of a *Succinea ovalis* population coincided with fluctuations in the soil moisture. Kunkel (1916) is of the opinion that water is the most important factor in the life of land mollusks. He states that response to stimulus, locomotion, copulation, and the differential mortality of young and old slugs was determined or modified largely by water. Van Cleave (1931), examining a tract of hardwoods in southern Illinois after the great drought of 1930, estimated that the drought had eradicated 99 per cent of the land snails.

The dependence of land snails on water may readily be observed in the field, most species being limited to quite moist habitats. When the snail's habitat dries out during a short dry period, nearly all of the snails will be in a state of aestivation, the aperture covered by an epiphragm. Sites exposed to sunlight and wind have poor land snail faunas.

Land snails generally are nocturnal in habit and seldom go abroad in the daylight. Oughton (1948) believes that "the lower rate of evaporation and the presence of dew probably are sufficient to explain the nocturnal activity of land snails."

Snails are more abundant in river valleys probably only because of the moisture and greater protection from wind and dessication. Oughton (1948) is of the opinion that in Ontario, water is significant only to the extent of determining the habitat and local abundance of land snails but not, by itself, the broad picture of geographical distribution.

Since one of the major soil factors in the development of the humus layer of forest soils is the moisture content of the soil (Diebold, 1935) , water in this way may indirectly have some influence on the distribution of land snails.

Hydrogen-Ion Concentration

"Empirical as it may be, the pH value exerts a definite influence upon the life functions of organisms, availability of nutrients, and physical properties of soils...However, the concept of pH must be freed from the misapprehensions which have been attached to it during the past thirty years. This should be particularly true in regard to generalizations such as those recently expressed by Pearsall (1952:50) in whose opinion "it may safely be said that the soil pH remains as the most useful single measurement that can be made for ecological purposes'..." (Wilde, 1954). Ashlander (1952) is of the opinion that the low productivity of acid soils is caused by a deficiency of nutrients rather than by soil reaction. Allee, et. al. (1949) say that "at least a part of the relation of plants and animals to acid soil is not to the H-ion concentration as such, but to accompanying calcium deficiency and altered physical properties."

Atkins and Lebour (1923) state that soil reaction is a limiting factor in the distribution of land snails in Ireland, snails being more numerous at pH 7 to 8 than at other pH values, with the number of species greatest at pH 7.0 Okland (1930) found that the distribution of land snails in Norway was correlated with different pH values. However, these reaction ranges were established by observing the distribution of snails in nature, a method which has little scientific justification. The occurrence of snails within certain pH ranges can be related to numerous conditions other than soil reaction, such as physical make up of the soil, content of available nutrients, and influences of climate.

Jacot (1940) says that "alkaline regions support a much more abundant and varied molluscan population." Strandine (1941) found in a Succinea ovalis population that during the months when the soil was most acid, the population was smaller. Strandine (1937, 1938) also found a marked correlation between the amount of calcium in the soil and pH. A high pH was associated with high calcium concentrations and a low pH was associated with low calcium concentrations. He found the most species at the higher pH ranges and calcium concentrations, although snails cultured in the laboratory on very acid or basic soils did not do as well as those on neutral soil. Oughton (1948) observed that snail species which were not restricted to limestone regions were relatively more abundant on the more alkaline soils. Archer (1939) found the largest number of species of land snails in oak-hickory communities, having a somewhat calcareous soil with a pH of about 7.0. Walton and Wright (1926) in North Wales, and Frömming (1936) in Germany, found that the hydrogen-ion concentration had scarcely any influence on the distribution of fresh-water snails.

Land snails of Hanover, Henrico, and Chesterfield Counties were found to occur in a pH range of 4.3 - 7.8, and most frequently at a pH range of 6.3 - 6.7 (Appendix L, Graphs 1 and 2). However, it is not to be inferred here that the hydrogen-ion concentration of the soil is a factor limiting the distribution of the snails, although it may play some minor role. Probably the correlation exists because the natural soils of deciduous forests in this region generally have a pH in the range of 6.3 - 6.7 and consequently the most snails are found at this pH range. The relationship between the pH value of soils and the distribution of snails is complicated by the influence of many other factors and hence does not permit broad generalizations.

Climate

Although climate may affect snail distribution over a large area it would not be expected to have an observable effect in the region concerned in this study. There is little difference in temperature, precipitation, and weather conditions in general over the three counties.

One factor which may explain the abundance of snails in woodlands is the more uniform environment and less extreme temperature changes. Dowdy (1944), in studying the influence of temperature on the vertical migration of invertebrates (including six species of mollusks) inhabiting different soil types, found that the invertebrate fauna of the soil responded readily to variations in temperature. The fauna moved to lower and warmer depths as the temperature dropped in the fall and early winter. As the temperature rose in the spring, the soil fauna moved back closer to the surface. Temperature was the most important single factor during colder periods in influencing this migration. However, he suggested that temperature and moisture must be considered together during the warmer periods of the year in which some of the animal groups tended to return deeper to the soil. These factors evidently account for finding fewer snails during the colder months and during hot, dry periods. Strandine (1938) suggests that the difference between the temperature of the air and soil may affect snail distribution. The present study throws no light on this influence.

Elevation

Although various authors have correlated snail distribution with elevation, the elevations of this region do not differ enough for inferences to be made as to its relation to land snail distribution. The differences in number of species and specimens in the Coastal Plain and the Piedmont Plateau can probably be explained by other factors, such as plant associations, soil structure, and general topography (cf. " Plant Associations").

Animal Associations and Predators

It may be concluded that predators, and in some cases competition, may have some influence on land snail abundance, but probably not on overall, general distribution. Boycott (1929, 1936) is of the opinion that competition between mollusks appears to play a minor role in the determination of habitat, but is not a factor limiting distribution. He states that predators seem to have little selective effect on determination of habitat or distribution. The sporadic distribution of a few species, e.g., *Gastrocopta armifera*, *Euconulus fulvus* , and *Pupoides albilabris*, may be due to accidental transport by some wide ranging agent, e.g., bird or man. However, the effect of these factors is obscure.

SUMMARY

One hundred and seventy-eight collections from one hundred and twenty-three stations have been made in Hanover, Henrico, and Chesterfield Counties Virginia between June, 1952, and November, 1953. Thirty-four species and subspecies representing ten families and three orders have been determined. Duplicate specimens have been deposited in the United States National Museum, Washington, D. C., the Academy of Natural Sciences of Philadelphia, and in the Collections of Dr. Paul R. Burch, Radford, Virginia.

Soil and leafmold samples taken from the land snail habitats were analyzed for organic matter, certain inorganic compounds, and pH. Ninety-four per cent of all snail specimens collected at these stations were found where the organic matter present in the samples was three per cent or greater; eighty-seven per cent of the specimens were found where the calcium oxide was 0.075 per cent or greater; fifty-nine per cent where the magnesium oxide was 0.018 per cent or greater; fifty-four per cent where the phosphoric acid was between 0.002 and 0.004 per cent; sixty-five per cent where the potash was 0.012 per cent or greater; and thirty-six per cent at a pH range of 6.3 to 6.7.

The primary factors regulating land snail distribution in this area seem to be calcium, moisture, organic matter, and cover. There is some correlation between land snail distribution, plant associations, and pH of the soil, but these appear to be of secondary importance.

There is a correlation between magnesium, potassium, and phosphorous, but too little is known at present about their effect on snail growth and metabolism to relate these factors to land snail distribution.

Land snail distribution cannot be explained by any one single environmental factor but apparently is a result of the interaction of a number.

LITERATURE CITED

Allee, W. C., Emerson, A. E., Park, O., Park, T., and Schmidt, K. P. 1949. Principles of animal ecology. Saunders Co. 223.

Archer, A. F. 1939. The ecology of the Mollusca of the Edwin S. George Reserve, Livingston County, Michigan. Occ. Papers Mus. Zool. U. Mich. (398) pp. 24.

Ashlander, A. 1952. Standard fertilization and liming as a factor in maintaining soil productivity. Soil sci. 74: 181-195.

Baker, F. C. 1939. Fieldbook of Illinois land snails. Ill. Nat. Hist. Survey. (2) pp. 166 + xi.

Bennett, H.H., and McLendon, W.E. 1906. Soil survey of Hanover County, Virginia. U. S. Dept. Agr. pp. 37.

Bevelander, G., and Benzer, P. 1948. Calcification in marine mollusks. Biol. Bull. Woods Hole. 94: 176-183

Bloomer, Robert Oliver. 1938. The geology of the Piedmont in Chesterfield and Henrico Counties, Virginia. M. S. Thesis, U. Va. 1-42.

Brockmeier, Heinreich. 1929. Landschnecken mit Gehause als Reagents auf kohlensauren Kalk. Ber. Senckenbergische Naturforsch. 59 (5): 254-256.

Burch, J.B. 1952. A preliminary list of the Mollusca of Hanover County, Virginia, Naut. 66(2): 60--63.

Burch, P.R. 1950. "Mollusks". <u>The James River Basin, Past, Present, and Future</u>. Va. Acad. Sci. 129-137.

Burch, P.R. 1952. Personal communication.

Burckill, H.J. 1944. Snails eating shells. North Western Nat. 19(3): 117.

Boycott, A.E. 1929. The ecology of British land Mollusca, with special reference to those of ill-defined habitat. Proc. Malac. Soc. London. 18(5): 213-224.

__________. 1934. The habitats of land Mollusca in Britain. Jour. Ecol. 22: 1--38.

__________. 1936. The relation of slugs and snails to man in Britain. Proc. Cotteswold Nat. Field Club. 26(1): 73-82.

Clapp, G.H. 1895. <u>Vitrina limpida</u> in western Pennsylvania. Naut. 9: 94.

________. 1900. Land Mollusca of Kennebunkport, Maine. Naut. 14: 63.

Clark, W.B., Miller, B.L., Berry, E.W., and Watson, T.L. 1912. The physiography and geology of the Coastal Plain Province of Virginia Va. Geol. Survey. 4: pp. 274.

Clarke, F.W., and Wheeler, W. C. 1922. The inorganic constituents of marine invertebrates. U.S.G.S. Prof. Papers. 124: 1-62.

Clench, W.J. 1930. Additional notes on the colony of Helix nemoralis at Marion, Massachusetts. Naut. 44: 14.

Dice, L.R. 1952. Natural communities. U. Mich. Press. pp. 34--44.

Diebold, C.H. 1935. Some relations between soil type and forest site quality. Ecol. 16(4): 640-647.

Dowdy, W.W. 1944. The influence of temperature on vertical migration of invertebrates inhabiting different soil types. Ecol. 25: 449-460.

Fenton, G.R. 1947. The soil fauna with special reference to the ecosystem of forest soil. Jour. Animal Ecol. 16: 76-93.

Frömming, Ewald. 1936. Uber den Einfluss der Wasserstoffinenkonzentration auf unsere Susswasserscknecken. Internat. Rev. Ges. Hydrolbiol. u. Hydrogr. 33: 25--37.

Giles, A. W. 1918. Geologic map of the state of Virginia. Va. geol. Survey.

Goodrich, Calvin. 1932. The Mollusca of Michigan. Mich. Handbook Series, U. Mich. Press. (5) : pp. 173.

________. and van der Schalie, Henry. 1944. Revision of the Mollusca of Indiana. Amer. Mid. Nat. 32: 1-70.

Hubricht, Leslie. 1953. Land snails of the southern Atlantic Coastal Plain. Naut. 66(4): 114-125.

Ingram, W.M. 1941. Habits of land Mollusca at Rensselaerville, Albany County, New York. Amer. Mid. Nat. 25(3): 644--651.

Jacot, A.P. 1935. Molluscan populations of old growth forests and rewooded fields in the Asheville basin of North Carolina. Ecol. 16: 603-605.

________. 1940. The fauna of the soil. Quart. Rev. Biol. 15: 28--58.

Kunkel, K. 1916. Zur Biologie der Lungenscknecken Ergebnisse vieljahr, Zuchtgr. v. Exper. veroffentlicht in Unterstutzg. d. Heidelberg Akad. d. Wissenschl. 440 ⁄ xvi.

Latimer, W.J., and Beck, M.W. 1913. Soil survey of Henrico County, Virginia. U. S. Dept. Agr. 145.

Lee, C. Bruce. 1952. Ecological aspects of Stenotrema hirsutum(Say) in the region of Ann Arbor, Michigan. Amer. Mid Nat. 47(1):55-60

Map of the State of Virginia. 1946. U. S. Geol. Survey.

Maps of the primary and secondary highway systems of Hanover, Henrico, and Chesterfield Counties, Virginia. 1952. Va. Dept. Highways.

Michaelson, E.H., 1953. A preliminary survey of the land mollusks of Alachua County, Florida. II. Naut. 67(2): 48-53.

Nafziger, Jacob. 1940. Bodenuntersuchungsergebnisse zum Kalkdungsuersuch, I. Fortswiss. Centralbl. 62(3): 59-64.

Nikiforoff, C.C. 1938. Soil organic matter and soil humus. Yearbook, U. S. Dept. Agr. 929-939.

Økland, Fridthjof. 1930. Quantitative Untersuchungen der Landschneckenfauna Norwegens. I. Zeitschr, Wiss. Biol. Ab. t. A. Zeitschr. Morphol. u. Ökol. Tiere. 16: 748-804.

Oldham, C. 1929. The influence of lime on the shell of Arianta arbustosum (L.) Proc. Malacol. Soc. London. 18(4): 143-144.

__________. 1934. Further observations on the influence of lime on the shells of snails. Proc. Malacol. Soc. London. 21:131--138.

Oughton, John. 1948. A zoogeographical study of the land snails of Ontario. Toronto Studies, Biol. Ser. 57: pp. 126.

Pearsall, W.H. 1952. The pH of natural soils and its ecological significance. Jour. Soil Sci. 3: 41-51.

Pearse, A.S. 1953. Land snails in the Duke Forest (Mollusca: Gastropoda). Jour. Tenn. Acad. Sci. 28(3); 185-186.

Perry, G.S. 1928. Calcium--key to forest productivity. Jour. Forest. 26(6): 767--773.

Pierre, W.H., and Allaway, W.H. 1941. Calcium in the soil. II. Biological relations. Soil. Sci. Soc. Amer. Proc. 6:16--26.

Pilsbry, Henry A. 1939-48. Land Mollusca of North America (North of Mexico). Acad. Nat. Sci. Phila. 1 and 2: pp. 2215 ⁄ xxvi.

__________. 1954. Personal communication.

Powell, A.W.B. 1949. The species problem in New Zealand land snails. Trans. Roy. Soc. N.Z. 77(5): 202-208.

Rehder, H.A. 1949. Some land and freshwater mollusks from the coastal region of Virginia and North And South Carolina. Naut. 62(4):121-126.

Reichert, Walther. 1927. Oekologische Beobachtungen über die positive Reaktionsfahigkeit der Gehauseschnecken gegenuber. Arch. Molluskenkunde. 59(5): 305-312.

Rensch, Bernhard. 1930. Eine biologische Reise nach den Kleinen Sunda-Inseln. Gebruder Borntraeger. 233--236.

Rich, C.I. 1953. Personal Communication.

__________. 1954. Personal communication.

Robertson, J.D. 1941. The function and metabolism of Ca in the invertebrates. Biol. Rev. 16:106--133.

Savely, H. E. 1939. Ecological relations of certain animals in dead pine and oak logs. Ecol. Monogr. 9:321-385.

Shimek, B. 1930. Land snails as indicators of ecological conditions. Ecol. 14(4): 673-686.

Strandine, Eldon J. 1937. Forest snail distribution in the Chicago area with especial reference to soil, Ecol. Soc. Amer. Bull. 18:52.

__________. 1938. Quantitative and experimental observations upon the distribution of forest snails in the Chicago area. Ecol. Soc. Amer. Bull. 19:39.

__________. 1941. Quantitative study of a snail population. Ecol. 22(1): 86-91.

Topographical quadrangle maps of Hanover, Henrico, and Chesterfield Counties, Virginia. 1917-1947. U. S. Geol. Survey.

Van Cleave, H.J. 1931. Some of the biological effects of drought. Sci. Monthly. 33: 301-306.

__________. 1951. Snails in their relations to the soil. The Biol. 34: 2--9.

Van der Schalie, Henry. 1939. Larger land snails from pine woods in Northern Michigan. Mich. Acad. Sci. Arts and Letters. 25: 367--370.

Walker, Bryant. 1928. The terrestrial shell-bearing Mollusca of Alabama. U. Mich. Misc. Pub. 18:pp. 180.

Walton, C.L., and Wright, W. Rees. 1926. Hydrogen-ion concentration and the distribution of Limnaea truncatula and L. peregra, with a note bearing mosquitoes. Parasitol. 18(4): 363-367.

Wilde, S. A. 1954. Reactions of soils: facts and fallacies. Ecol. 35(1): 89-92.

APPENDIX

LIBRARY
UNIVERSITY OF RICHMOND
VIRGINIA

A P P E N D I X A

FIELD DATA SHEET

Collection #____

Physiographic Range:________________________________

County:____

Locality:____

Altitude:____

Immediate Vicinity:_________________________________

Major Vegetation in Vicinity:________________________

Habitat:____

pH:_____________________________________

%CaO:___________________________________

%MgO:___________________________________

%P_2O_5:_________________________________

%K_2O:___________________________________

%Organic Matter:___________________________

NO. SPECIMENS_____________________________

NO. SPECIES_______________________________

Date of Collection:_______________________________

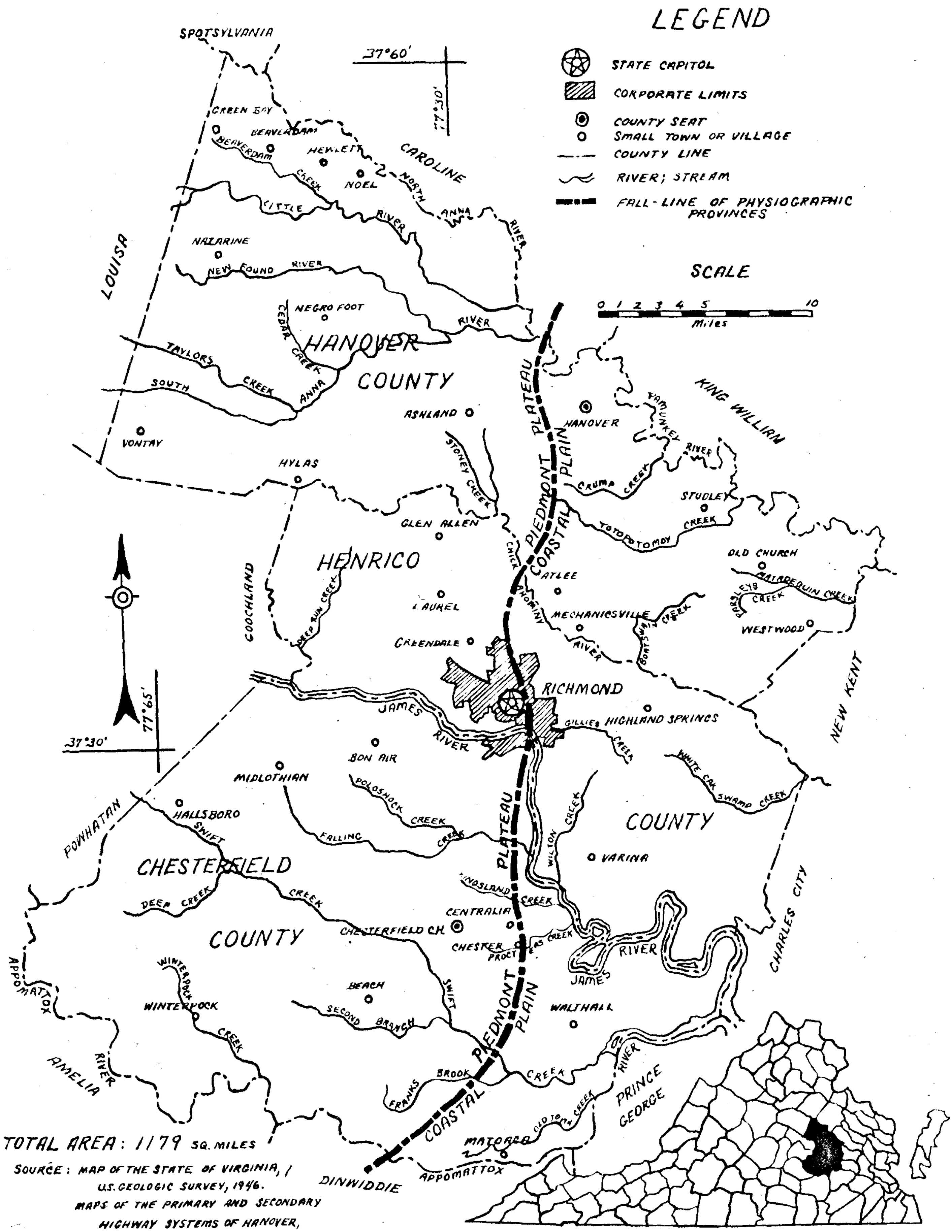
Weather:____

Temperature:______________________________________

Mollusca:____

A P P E N D I X B

MAP OF HANOVER, HENRICO, AND CHESTERFIELD COUNTIES, VIRGINIA



TOTAL AREA: 1179 SQ. MILES

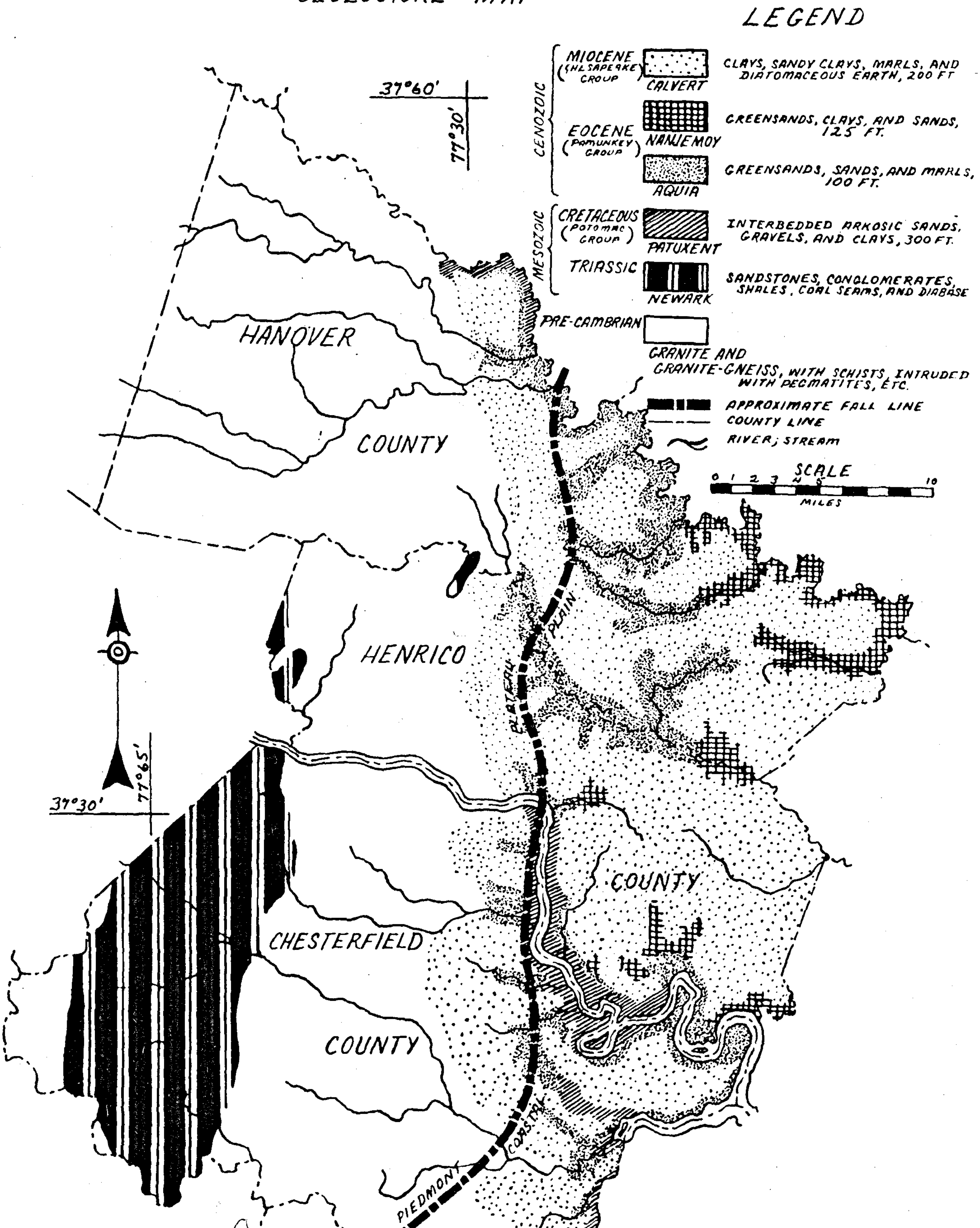
SOURCE: MAP OF THE STATE OF VIRGINIA, U.S. GEOLOGIC SURVEY, 1946.
MAPS OF THE PRIMARY AND SECONDARY HIGHWAY SYSTEMS OF HANOVER, HENRICO, AND CHESTERFIELD COUNTIES, VA. 1952.

APPENDIX C

GEOLOGIC MAP OF HANOVER, HENRICO, CHESTERFIELD COUNTIES, VIRGINIA

MAP 11

GEOLOGICAL MAP

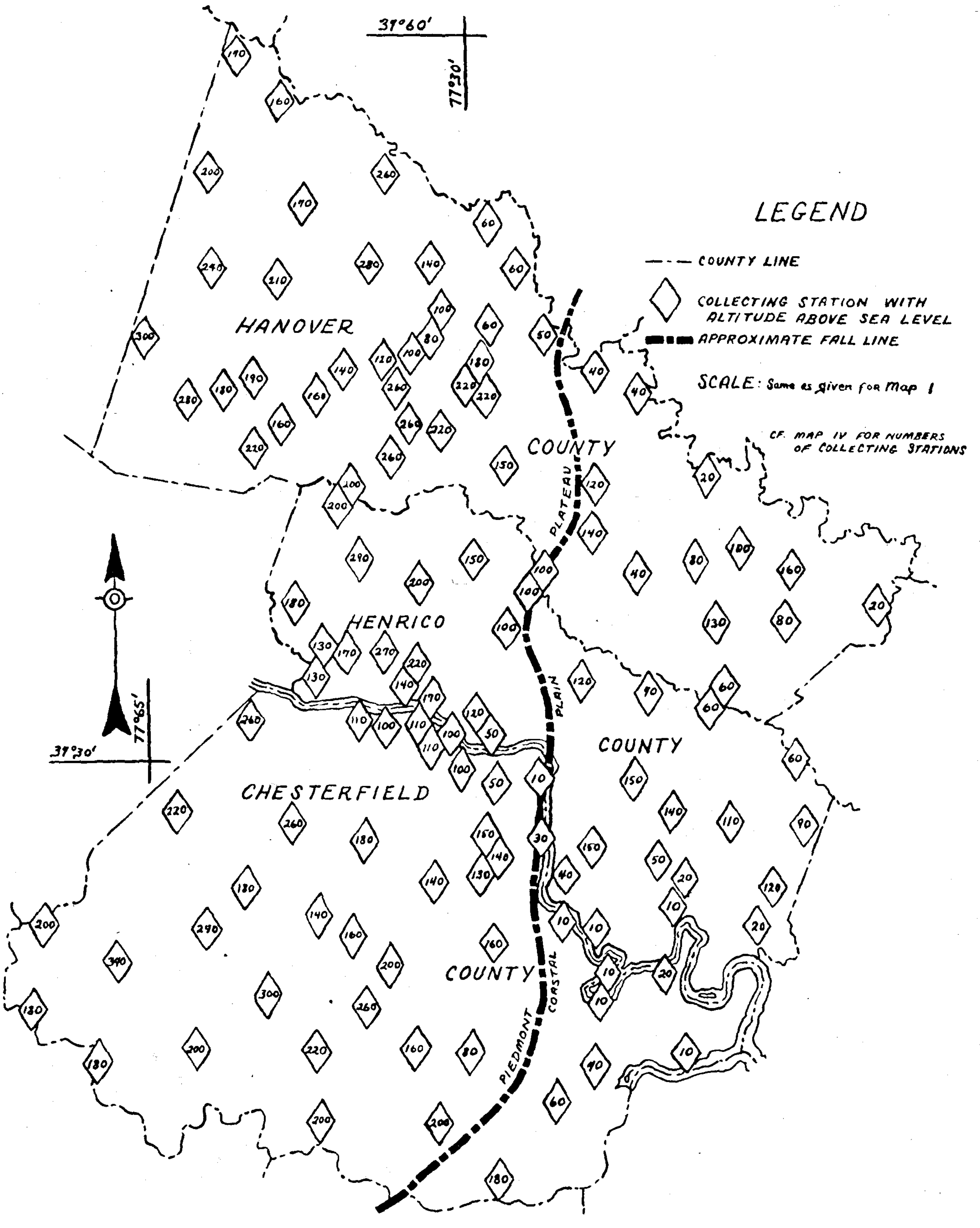


SOURCE: CLARK, ET EL; 1912
GILES; 1918

A P P E N D I X   D

MAP OF COLLECTING STATIONS WITH ELEVATIONS ABOVE SEA LEVEL

MAP III


37°60'
77°30'
HANOVER
COUNTY
HENRICO
CHESTERFIELD
COUNTY
COUNTY
PLATEAU
PLAIN
PIEDMONT
COASTAL
37°30'
77°65'
LEGEND
COUNTY LINE
COLLECTING STATION WITH ALTITUDE ABOVE SEA LEVEL
APPROXIMATE FALL LINE
SCALE: Same as given for Map I
CF. MAP IV FOR NUMBERS OF COLLECTING STATIONS

A P P E N D I X E

KEY TO COLLECTING STATIONS

KEY TO COLLECTING STATIONS

1. Davenport Bridge, North Anna River, VA. 658, Hanover County
2. North Anna River, VA. 738, Hanover County
3. Little River, VA. 680, Hanover County
4. Little River, VA. 738, Hanover County
5. VA. 684, ½ mile west of Noel, Hanover County
6. New Found River, VA. 715, Hanover County
7. New Found River, VA. 658, Hanover County
8. Hopeful Church, crossing of VA. 610 and VA. 664. Hanover County
9. Springfield Church, VA. 611. Hanover County
10. South Anna River, VA. 611, Hanover County
11. Taylor's Creek, VA. 691, Hanover County
12. Goldmine Creek, VA. 271, Hanover County
13. South Anna River, VA. 673, Hanover County
14. Ground Squirrel Bridge Wayside, South Anna River, U.S. 33, Hanover County
15. South Anna River, VA. 657, Hanover County
16. VA. 738, 3 miles west of Oliver,Hanover County
17. Little River, VA. 688 (near Hanover Academy,) Hanover County
18. Steel Bridge, North Anna River, U.S. 1, Hanover County
19. Stagg Creek, Va. 54, Hanover County
20. Woods behind Sycamore Hall, VA. 657, Hanover County
21. Horseshoe Bridge, South Anna River, VA. 686, Hanover County
22. Blunt's Bridge, South Anna River, VA. 667, Hanover County
23. New Found River, VA. 667, Hanover County
24. Chichahominy River, VA. 624, Hanover County
25. Va. 625, 1.8 miles southeast of VA. 623, Hanover County
26. Sycamore Hall, Va. 657, Hanover County
27. Professor Packard's House, VA. 657, Hanover County
28. College Heights, Ashland, Hanover County
29. Ashland, along R.R. tracks near Randolph-Macon College, Hanover County
30. Railroad Pond, Falling Creek, Hanover County
31. Newman's Mill, South Anna River, U. S. 1, Hanover County
32. Morris Bridge, North Anna River, VA. 602, Hanover County
33. South Anna River, VA. 688, Hanover County
34. VA. 660, ½ mile east of U. S. 1, Hanover County
35. Page's Bridge, Pamunkey River, VA. 2, Hanover County
36. Norman's Bridge, Pamunkey River, VA. 614, Hanover County
37. Hanover Wayside, Kersey Creek, U.S. 301, Hanover County
38. Totopotomoy Creek, U.S. 301, Hanover County
39. Totopotomoy Creek, VA. 606, Hanover County
40. Nelson's Bridge, Pamunkey River, VA. 615, Hanover County
41. Hawe's Millrace Creek, VA. 615, Hanover County
42. Totopotomoy Creek, VA. 606, west, Hanover County
43. Immanuel Church, VA. 606, Hanover County
44. Matadequin Creek, VA. 606, Hanover County
45. Parsley's Creek, VA. 628, Hanover County
46. Sandy Valley Creek, VA. 635, Hanover County
47. Grapevine Bridge, Chickahominy River, VA. 156, Hanover County
48. Chickahominy River, U.S. 301, Hanover County
49. Chickahominy River, VA. 624, Henrico County
50. U. S. 250, 1 3/4 miles east of Short Pump, Henrico County

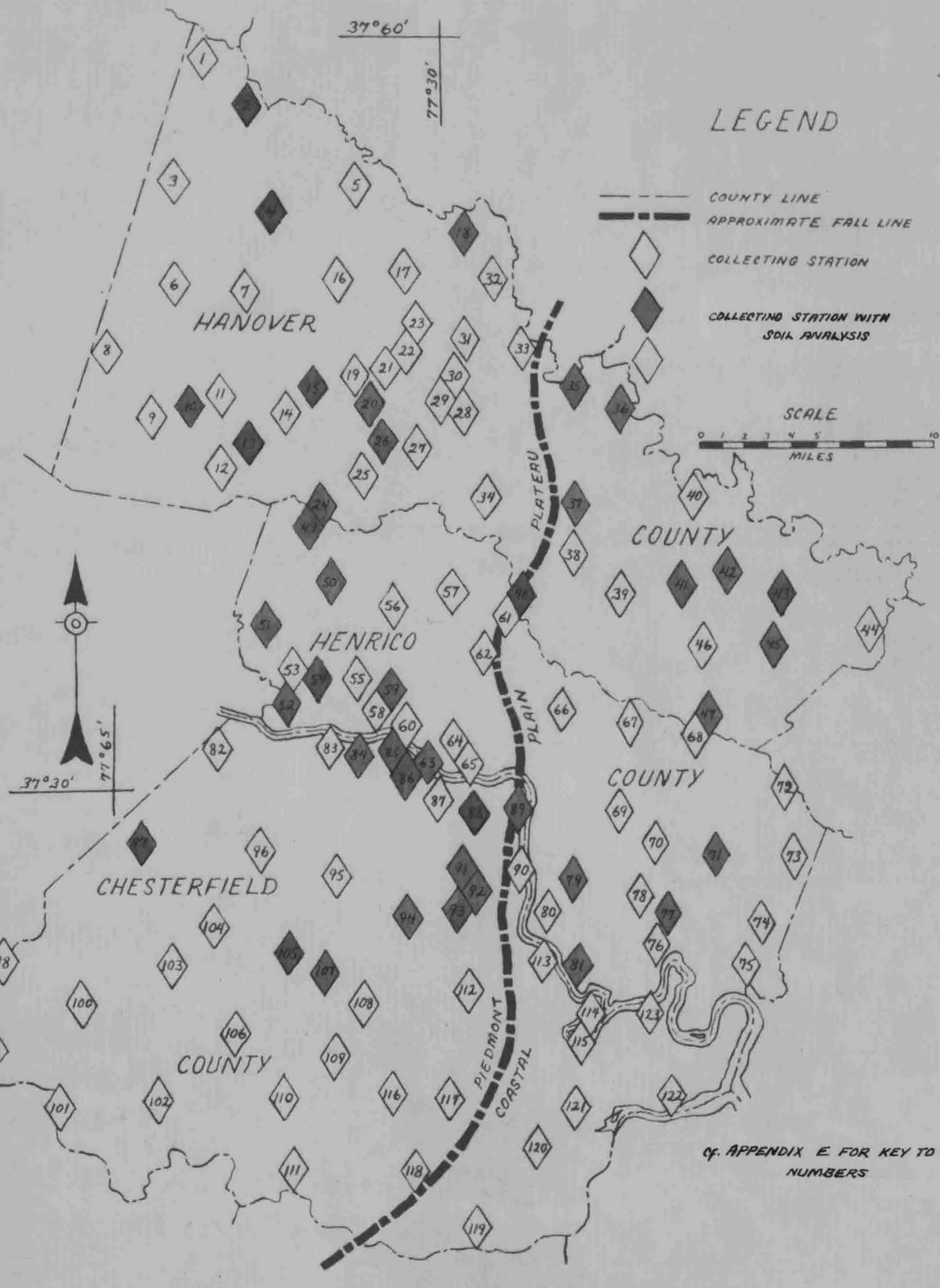
51. Old Coal Mine on Gayton Road, VA. 706, Henrico County
52. Tuckahoe Creek, VA. 650, Henrico County
53. VA. 6, 6 miles west of Richmond, Henrico County
54. Va. 6 and VA. 157, Henrico County
55. Ridge Road and Julian Road, near Richmond, Henrico County
56. Laurel Pond, Hungry Creek, U. S. 33, Henrico County
57. VA. 625, and VA. 682, Henrico County
58. Westhampton Lake, University of Richmond, Henrico County
59. Garden behind Westhampton College, Henrico County
60. Dr. Smart's Residence, 7003 University Drive, near U. Richmond, Henrico County
61. Chickahominy River, U.S. 301, Henrico County
62. Brook Run, U. S. 1, Henrico County
63. Rock quarry near James River, VA. 679, Chesterfield County
64. Maymont Park, Richmond, Va., Henrico County
65. James River, U. S. 1, Henrico County
66. Small Creek on Glenwood Golf Course, VA. 664, Henrico County
67. Chickahominy River, VA. 615, Henrico County
68. Grapevine Bridge, Chickahominy River, VA. 156, Henrico County
69. Fort Lee Baptist Church, VA. 600, Henrico County
70. White Oak Swamp Creek, VA. 802, Henrico County
71. White Oak Swamp Creek, VA. 717, Henrico County
72. Bottom's Bridge, Chickahominy River, U.S. 60, Henrico County
73. White Oak Swamp Creek, VA., 156, Henrico County
74. Willis' Church, VA. 156, Henrico County
75. VA. 5, near Turkey Island Creek, Henrico County
76. James River, VA. 602, Henrico County
77. Creek on VA. 603 between VA. 5 and VA. 602, Henrico County
78. Fourmile Creek, VA. 5, Henrico County
79. Saint James Baptist Church, VA. 5, Henrico County
80. Wilton Creek, VA. 611, Henrico County
81. James River, VA. 605, Henrico County
82. VA 44, 2 miles west of Robious, Chesterfield County
83. Bolsher's Dam, James River, VA. 704, Chesterfield County
84. James River, 1 mile west of Huguenot (Westham) Bridge, VA. 679, Chesterfield County
85. James River, ½ mile east of Huguenot Bridge, VA. 679, Chesterfield County
86. James River, 3/4 mile east of huguenot Bridge, VA. 679, Chesterfield County
87. James River, Atlantic Coast Line R.R. Bridge, Richmond, Chesterfield County
88. James River, U.S. 1, Chesterfield County
89. James River, near Diesel Housing Unit, Richmond, Chesterfield County
90. Creek flowing into James River, South Richmond, Chesterfield County
91. Falling Creek, VA. 10, near roadside, Chesterfield County
92. Falling Creek, VA. 10, near pond, Chesterfield County
93. VA. 10, ¼ mile east of Falling Creek, Chesterfield County
94. Falling Creek, VA. 651, Chesterfield County
95. Falling Creek, VA 653, Chesterfield County
96. U. S. 60, ¼ mile east of Midlothian, Chesterfield County
97. Turkey Creek, VA. 606, Chesterfield County

98. Skinquarter Creek, VA 603, Chesterfield County
99. Appomattox River, U. S. 360, Chesterfield County
100. U. S. 360, $\frac{1}{4}$ mile east of Skinquarter, Chesterfield County
101. VA. 602, 2 miles east of Bevil's Bridge, Appomattox River, Chesterfield County
102. Winterpock Creek, VA 602, Chesterfield County
103. VA. 690 and VA. 667, Chesterfield County
104. Branch Creek, Va. 668, Chesterfield County
105. Swift Creek, VA. 654, Chesterfield County
106. VA. 659, 1 mile north of intersection of VA. 655, Chesterfield County
107. VA. 653, near Pocahontas State Park, Chesterfield County
108. VA. 655, 3 miles west of Chesterfield, Chesterfield County
109. VA. 654, 1 mile north of Beach, Chesterfield County
110. VA. 653, $1\frac{1}{4}$ miles north of VA. 602, Chesterfield County
111. cattle Creek, VA. 657, Chesterfield County
112. VA. 611 and VA. 642, Chesterfield County
113. James River, VA. 656, Chesterfield County
114. James River Canal, VA. 615, Chesterfield County
115. James River, across from Farrar's Island, Chesterfield County
116. Second Brachn, VA. 636, Chesterfield County
117. Swift Creek, VA. 631, Chesterfield County
118. Gills Pond, VA. 628, Chesterfield County
119. Appomattox River, VA. 600, Chesterfield County
120. Swift Creek, VA. 625, Chesterfield,County
121. Creek across VA. 619, 3/4 mile east of VA. 620, Chesterfield County
122. R. R. Bridge crossing Appomattox River 6 miles west of Hopewell Bridge, Chesterfield County
123. James River, VA. 746, Chesterfield County

A P P E N D I X F

MAP OF COLLECTING STATIONS WHERE SOIL ANALYSES WERE MADE

MAP IV

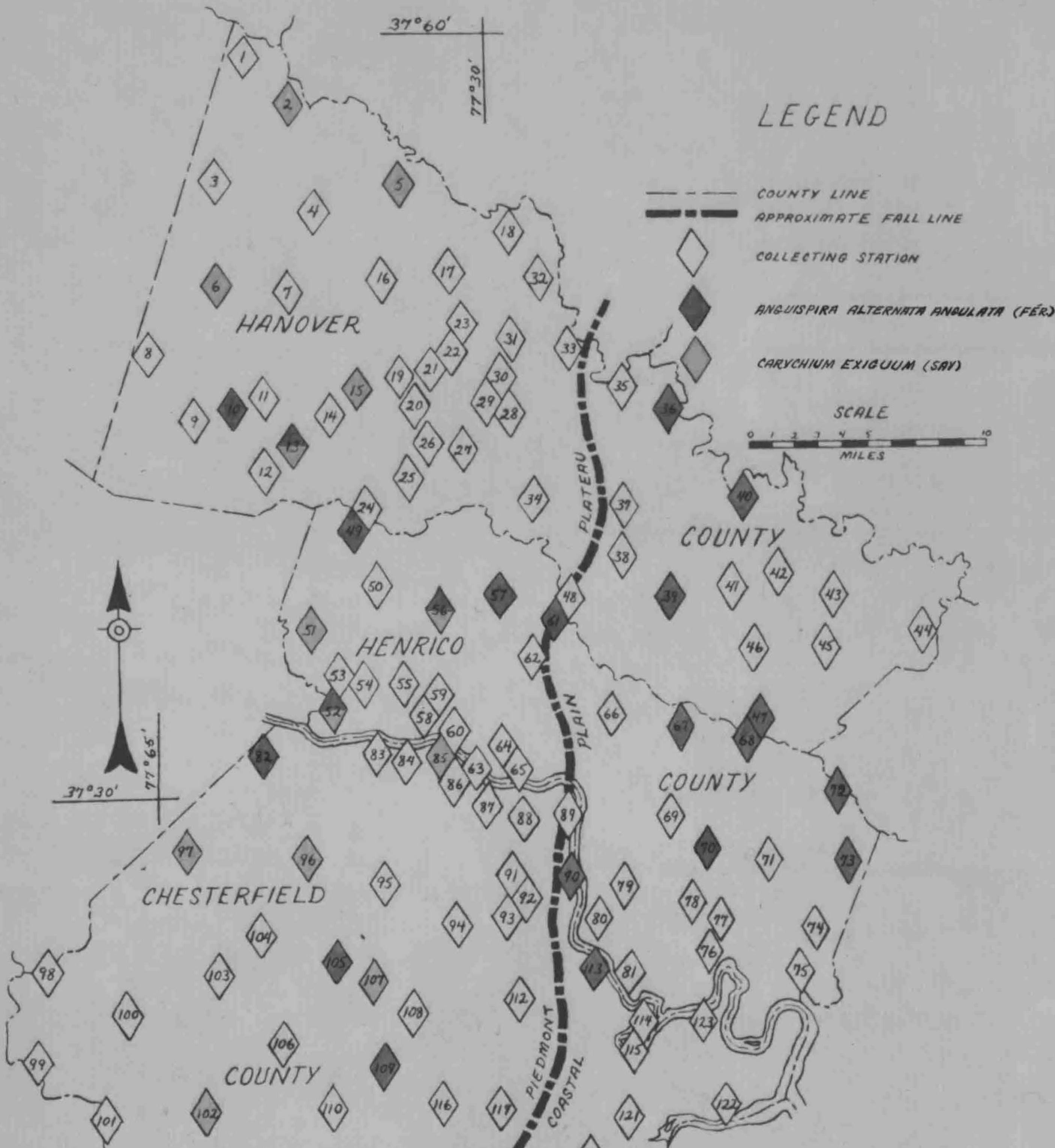


37°60'
77°30'
LEGEND
COUNTY LINE
APPROXIMATE FALL LINE
COLLECTING STATION
COLLECTING STATION WITH SOIL ANALYSIS
SCALE
0 1 2 3 4 5 10
MILES
HANOVER
HENRICO
COUNTY
COUNTY
CHESTERFIELD
COUNTY
PLATEAU
PLAIN
PIEDMONT
COASTAL
37°30'
77°65'
cf. APPENDIX E FOR KEY TO NUMBERS

A P P E N D I X G

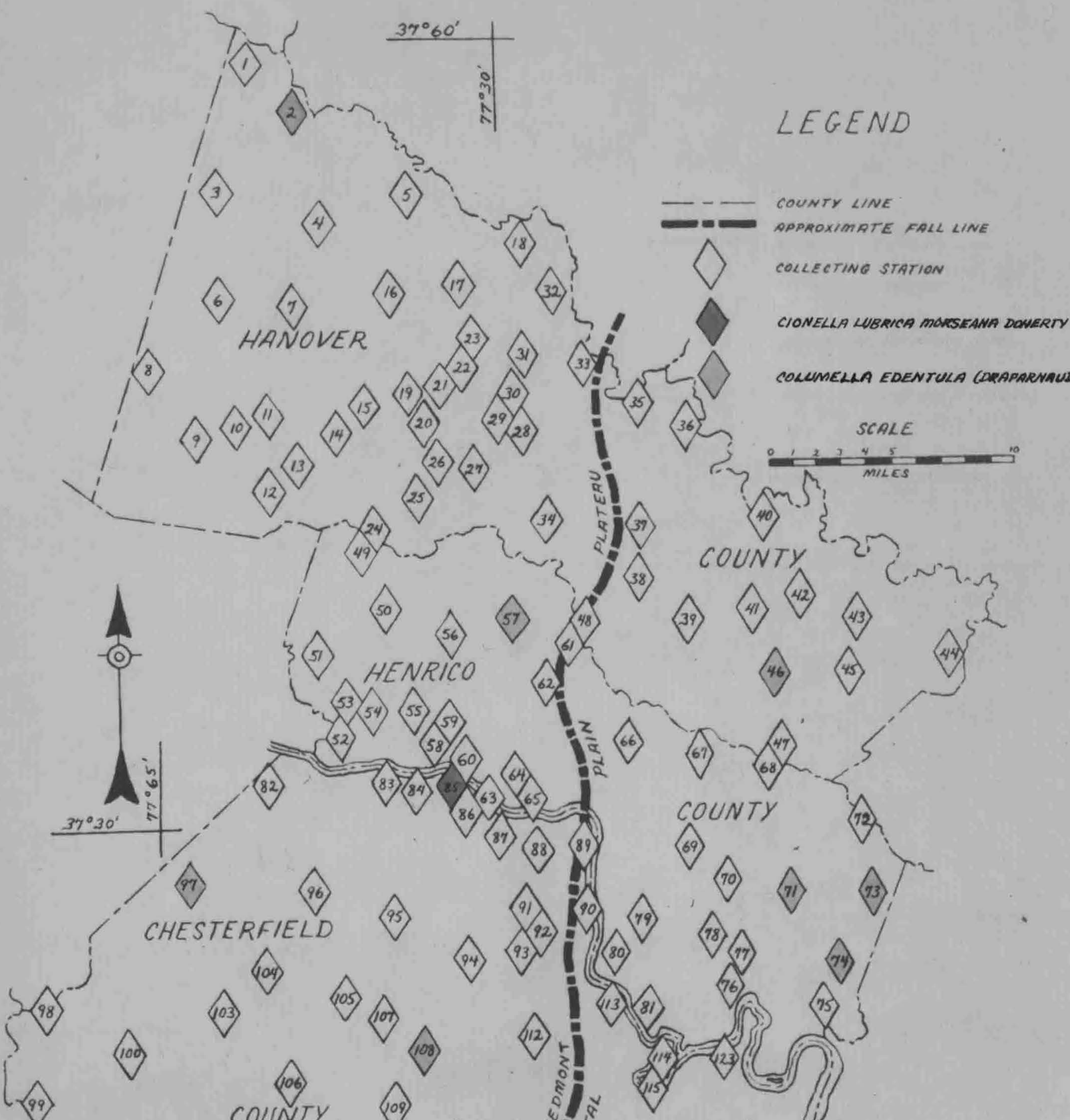
DISTRIBUTION MAPS

MAP V



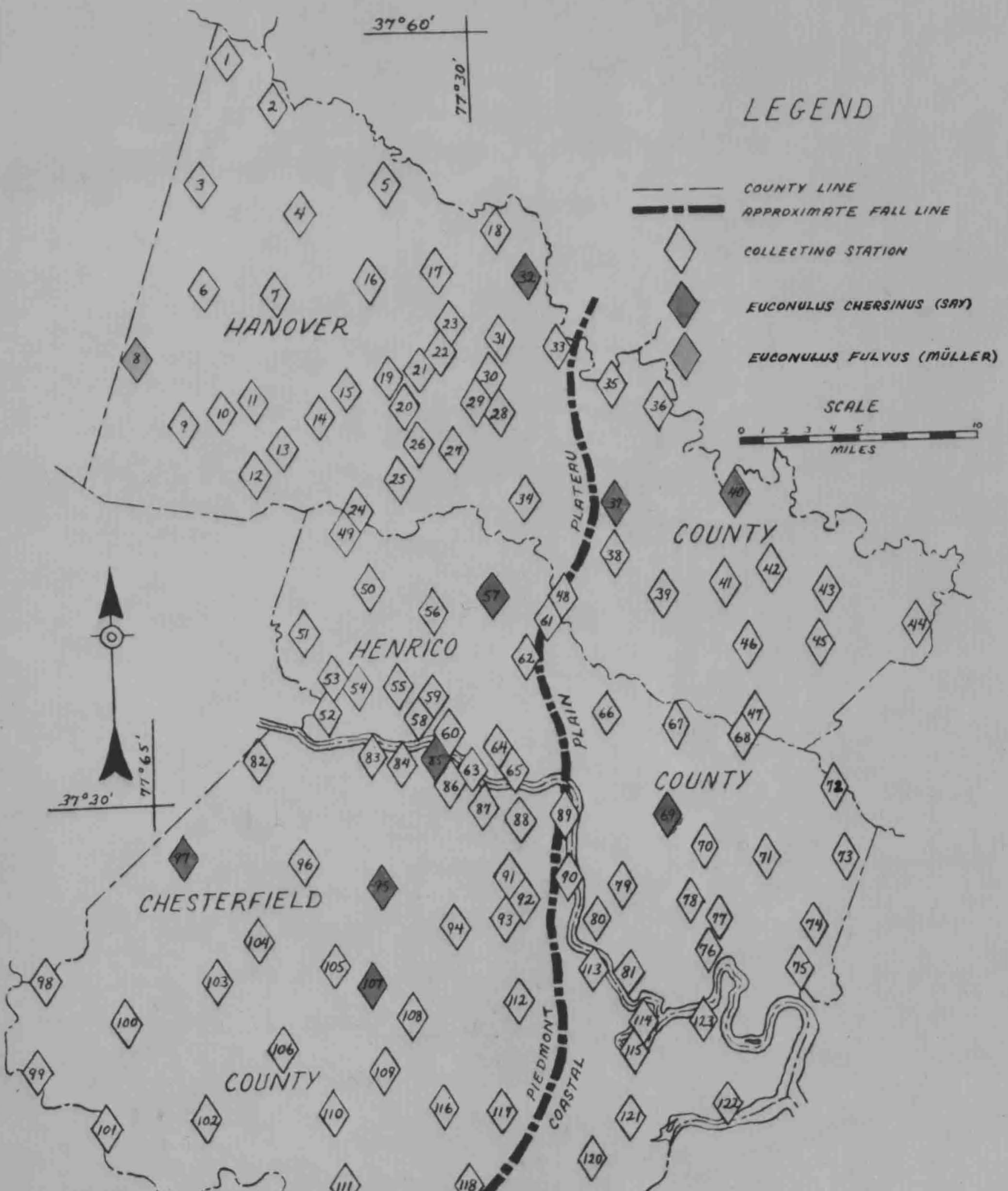
37°60'
77°30'
LEGEND
COUNTY LINE
APPROXIMATE FALL LINE
COLLECTING STATION
ANGUISPIRA ALTERNATA ANGULATA (FÉR)
CARYCHIUM EXIGUUM (SAY)
SCALE
0 1 2 3 4 5 10
MILES
HANOVER
COUNTY
HENRICO
COUNTY
CHESTERFIELD
COUNTY
PLATEAU
PLAIN
PIEDMONT
COASTAL
37°30'
77°65'

MAP VI



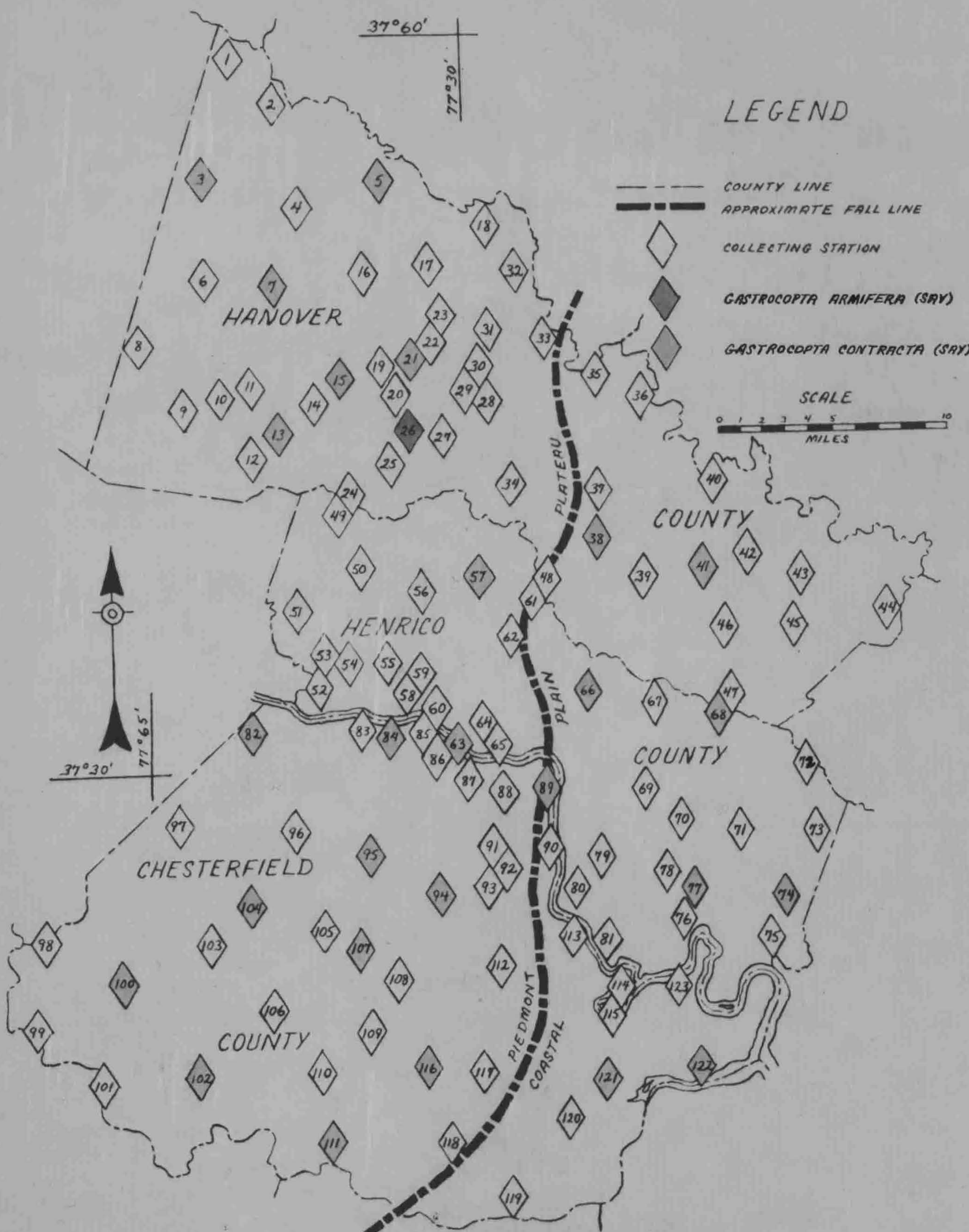
37°60'
77°30'
LEGEND
COUNTY LINE
APPROXIMATE FALL LINE
COLLECTING STATION
CIONELLA LUBRICA MORSEANA DOHERTY
COLUMELLA EDENTULA (DRAPARNAUD)
SCALE
MILES
HANOVER
COUNTY
HENRICO
COUNTY
CHESTERFIELD
COUNTY
PLATEAU
PLAIN
PIEDMONT
COASTAL
37°30'
77°65'

MAP VII



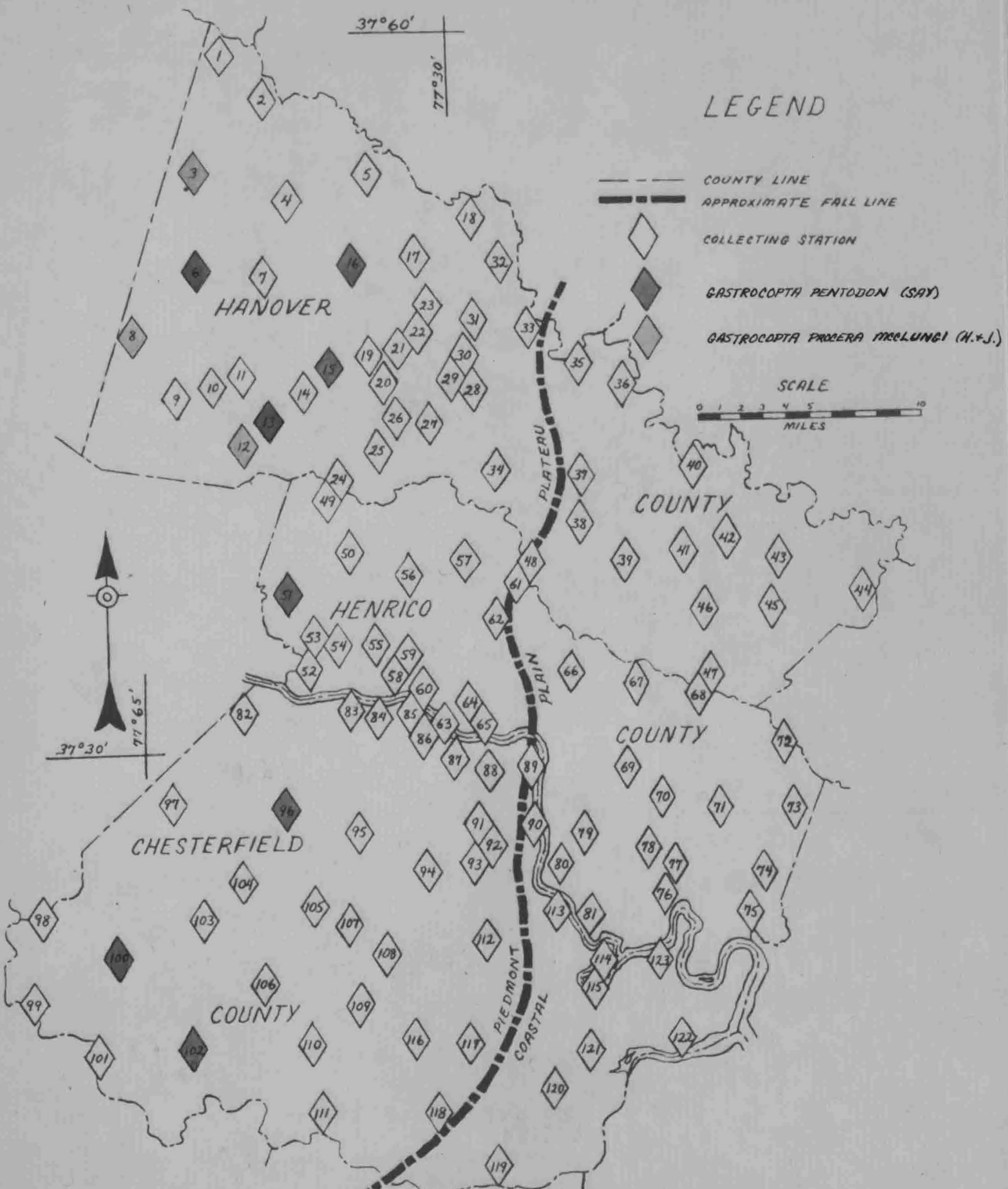
37°60'
77°30'
LEGEND
COUNTY LINE
APPROXIMATE FALL LINE
COLLECTING STATION
EUCONULUS CHERSINUS (SAY)
EUCONULUS FULVUS (MÜLLER)
SCALE
MILES
HANOVER
COUNTY
HENRICO
COUNTY
CHESTERFIELD
COUNTY
PLATEAU
PLAIN
PIEDMONT
COASTAL
37°30'
77°65'

MAP VIII

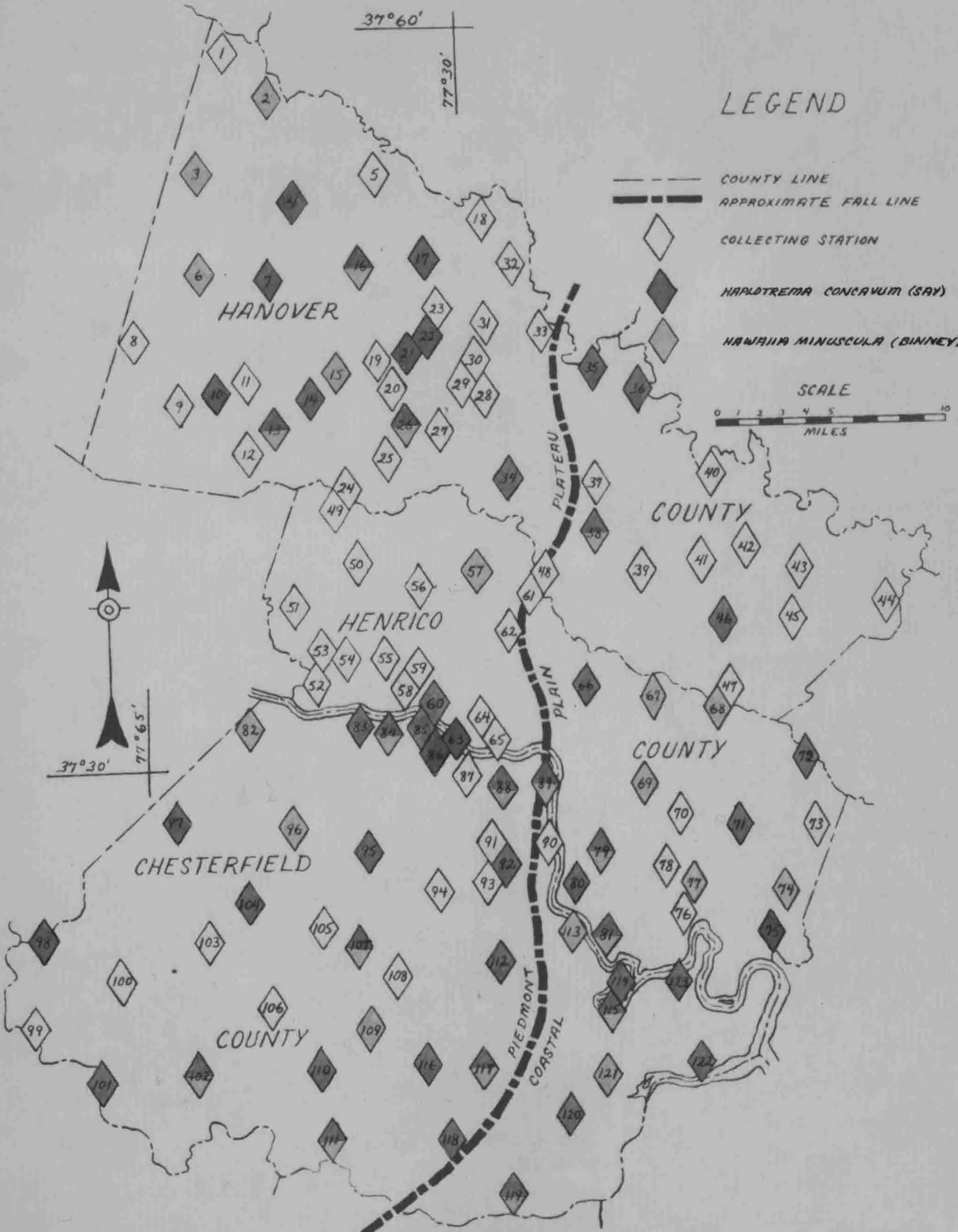


37°60'
77°30'
LEGEND
COUNTY LINE
APPROXIMATE FALL LINE
COLLECTING STATION
GASTROCOPTA ARMIFERA (SAY)
GASTROCOPTA CONTRACTA (SAY)
SCALE
MILES
HANOVER
COUNTY
HENRICO
COUNTY
CHESTERFIELD
COUNTY
PLATEAU
PLAIN
PIEDMONT
COASTAL
37°30'
77°65'

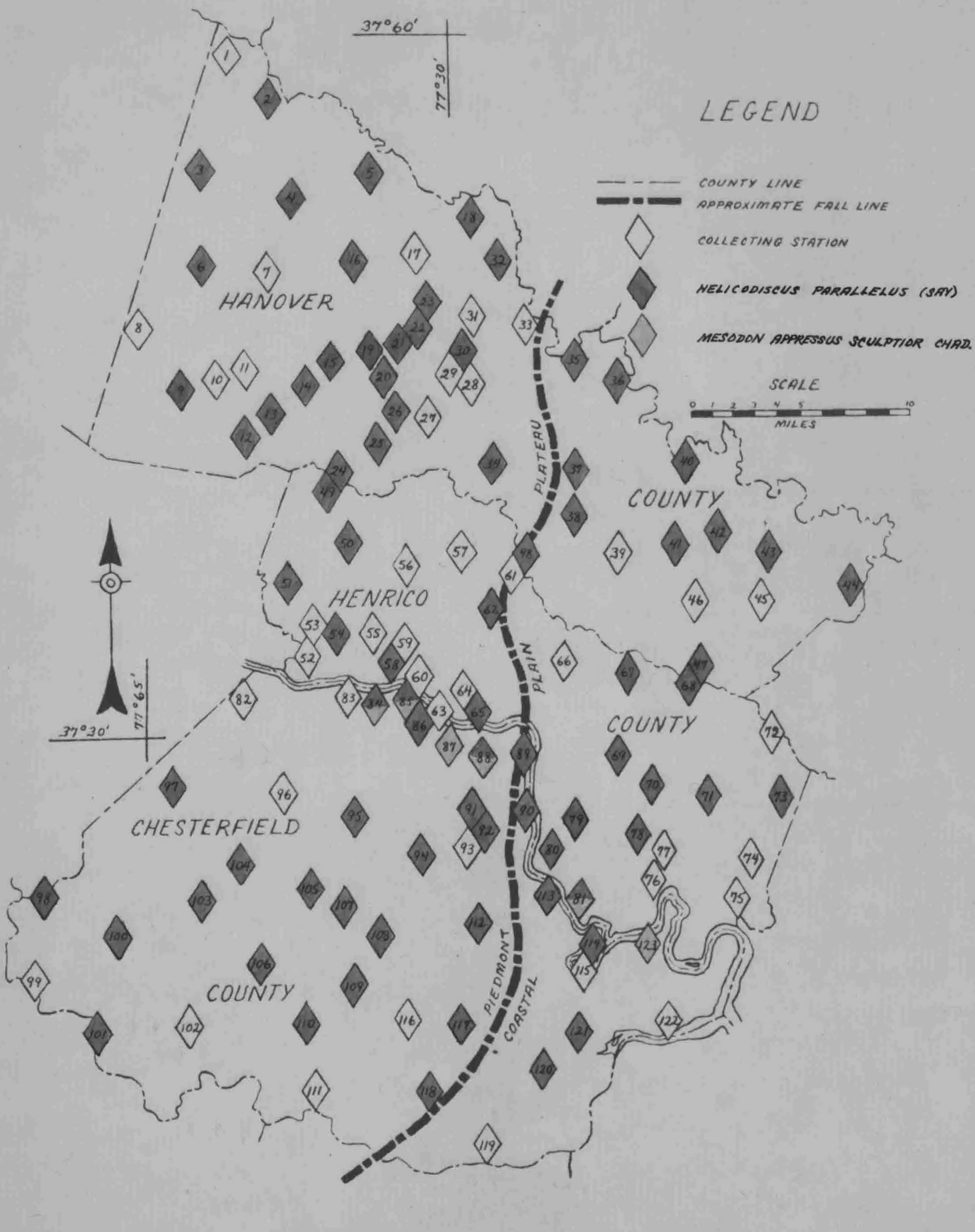
MAP IX


37°60'
77°30'
LEGEND
COUNTY LINE
APPROXIMATE FALL LINE
COLLECTING STATION
GASTROCOPTA PENTODON (SAY)
GASTROCOPTA PROCERA McCLUNGI (H.+J.)
SCALE
0 1 2 3 4 5 10
MILES
HANOVER
HENRICO
COUNTY
COUNTY
CHESTERFIELD
COUNTY
PLATEAU
PLAIN
PIEDMONT
COASTAL
37°30'
77°65'

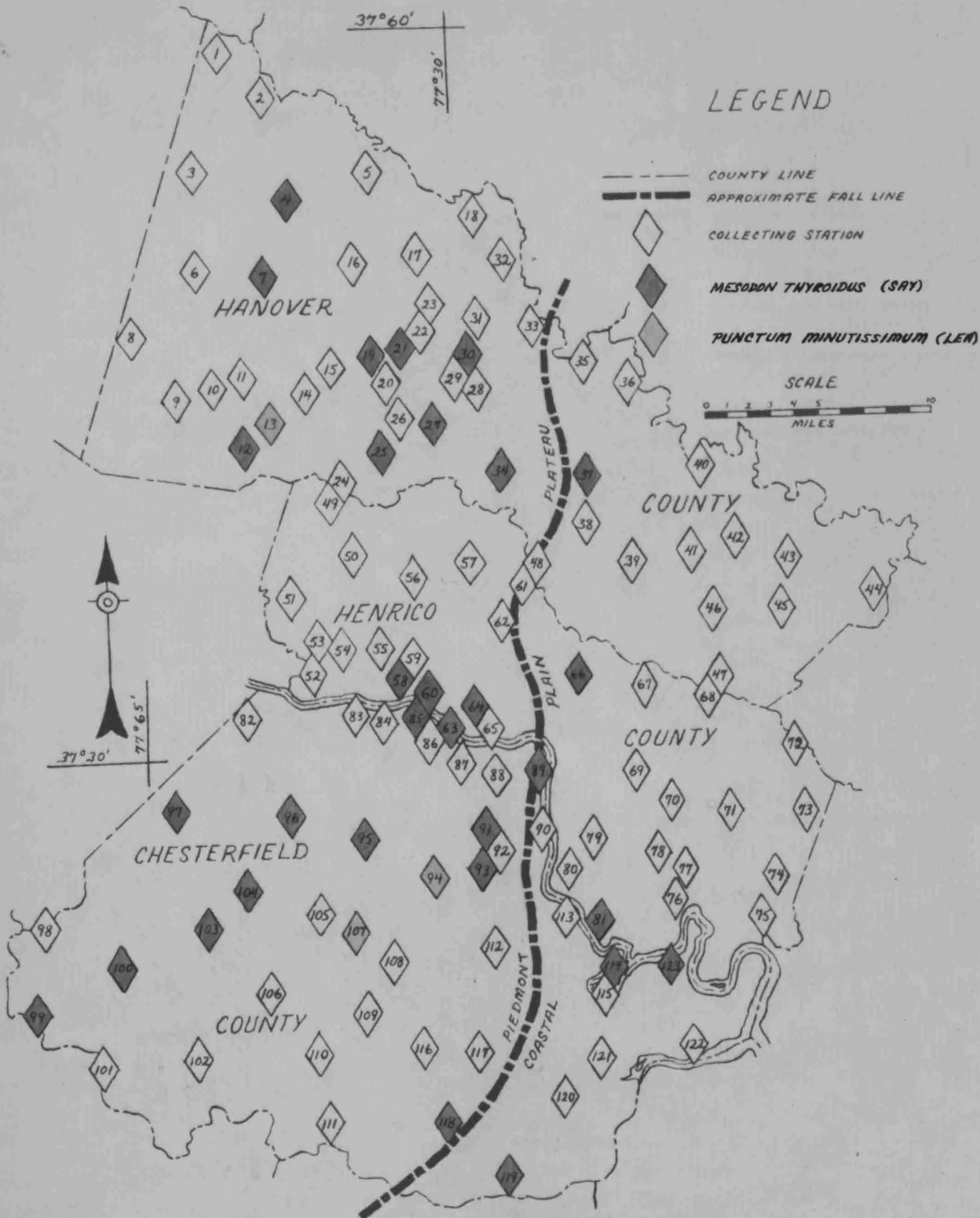
MAP X


37°60'
77°30'
LEGEND
COUNTY LINE
APPROXIMATE FALL LINE
COLLECTING STATION
HAPLOTREMA CONCAVUM (SAY)
HAWAIIA MINUSCULA (BINNEY)
SCALE
0 1 2 3 4 5 10
MILES
HANOVER
COUNTY
HENRICO
COUNTY
CHESTERFIELD
COUNTY
PLATEAU
PLAIN
PIEDMONT
COASTAL
37°30'
77°65'

MAP XI

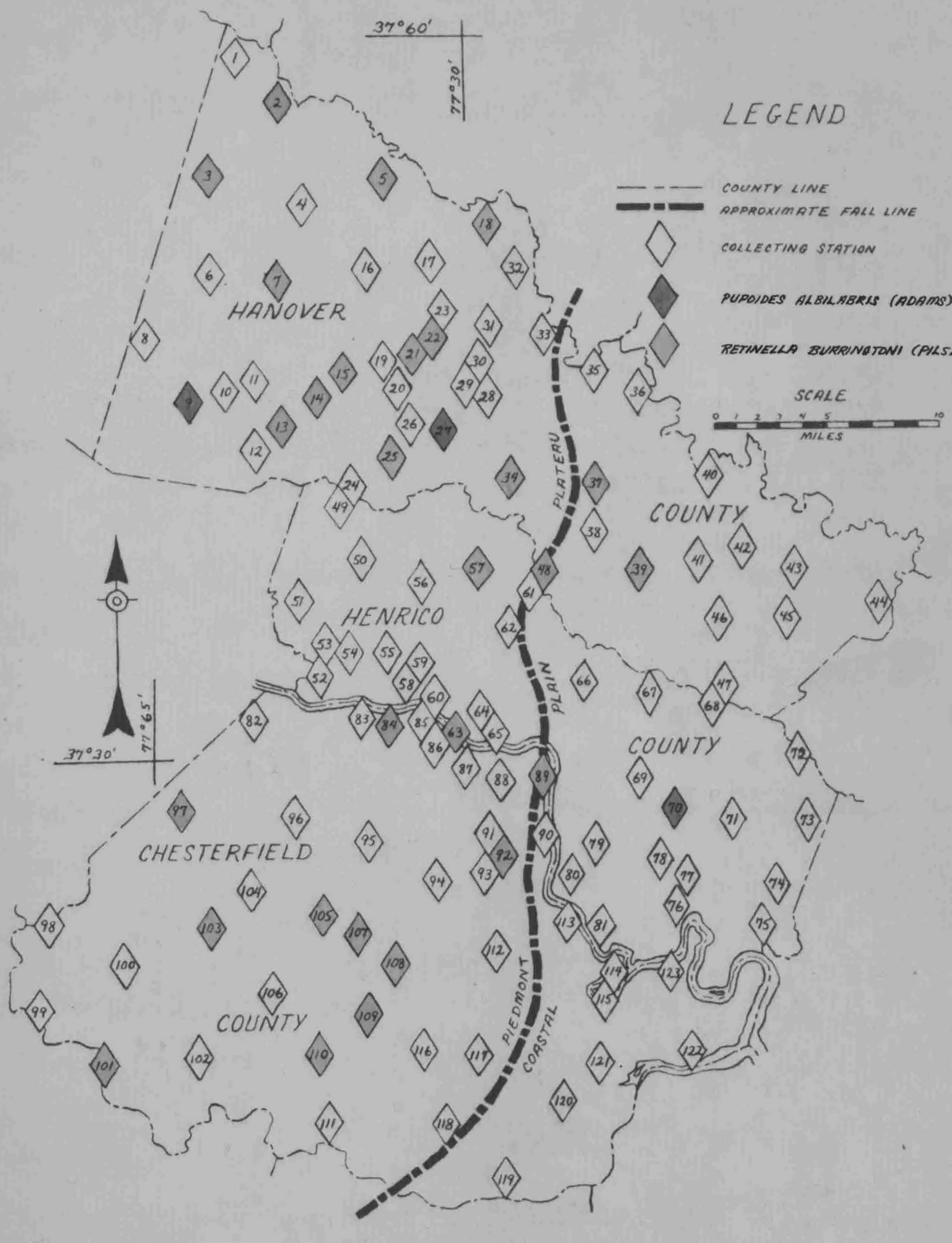

37°60'
77°30'
LEGEND
COUNTY LINE
APPROXIMATE FALL LINE
COLLECTING STATION
HELICODISCUS PARALLELUS (SAY)
MESODON APPRESSUS SCULPTIOR CHAD.
SCALE
0 1 2 3 4 5 10
MILES
HANOVER
HENRICO
COUNTY
COUNTY
CHESTERFIELD
COUNTY
PLATEAU
PLAIN
PIEDMONT
COASTAL
37°30'
77°65'

MAP XII

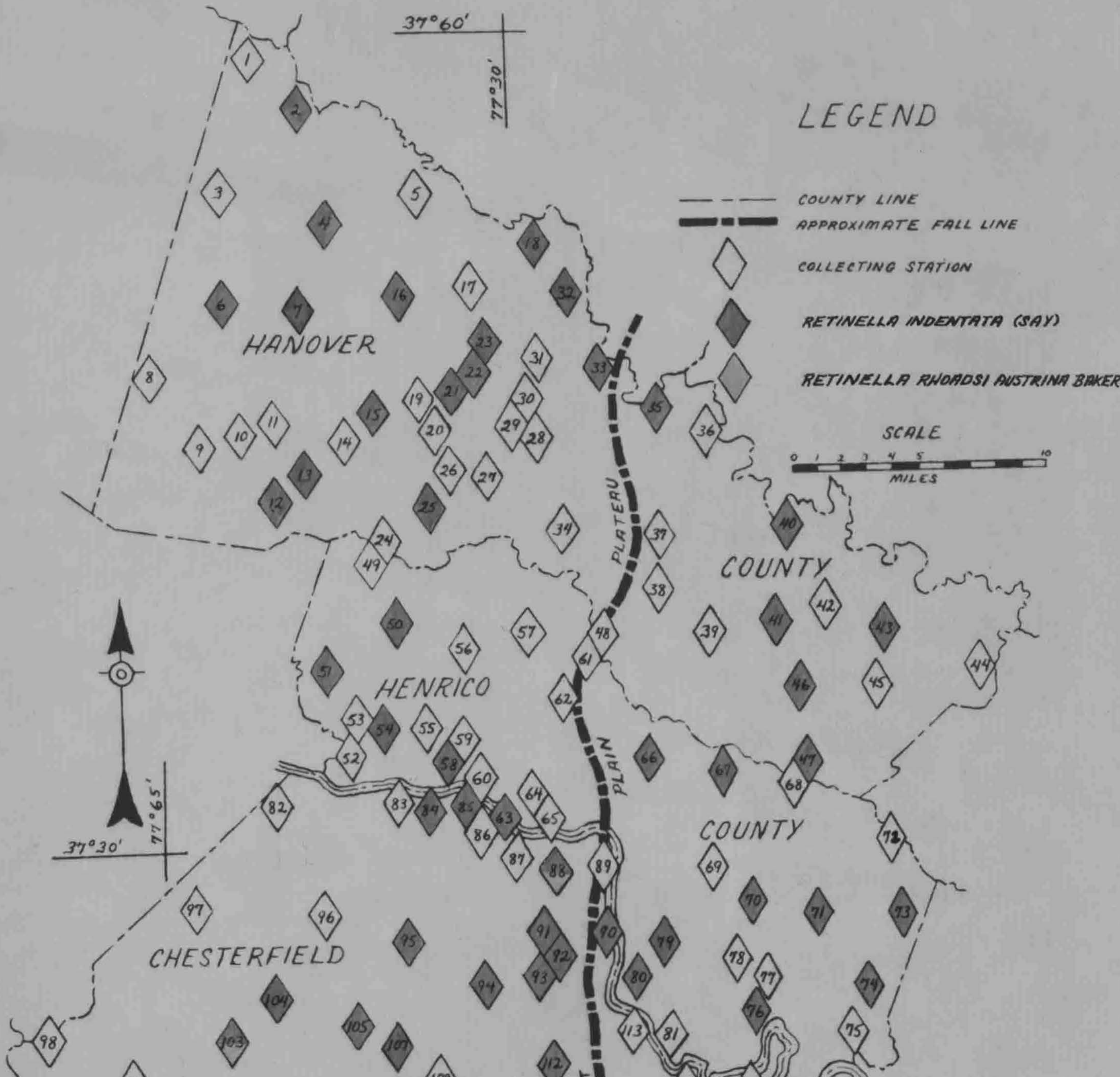


37°60'
77°30'
LEGEND
COUNTY LINE
APPROXIMATE FALL LINE
COLLECTING STATION
MESODON THYROIDUS (SAY)
PUNCTUM MINUTISSIMUM (LEA)
SCALE
MILES
HANOVER
COUNTY
HENRICO
COUNTY
CHESTERFIELD
COUNTY
PIEDMONT
PLATEAU
COASTAL
PLAIN
37°30'
77°65'

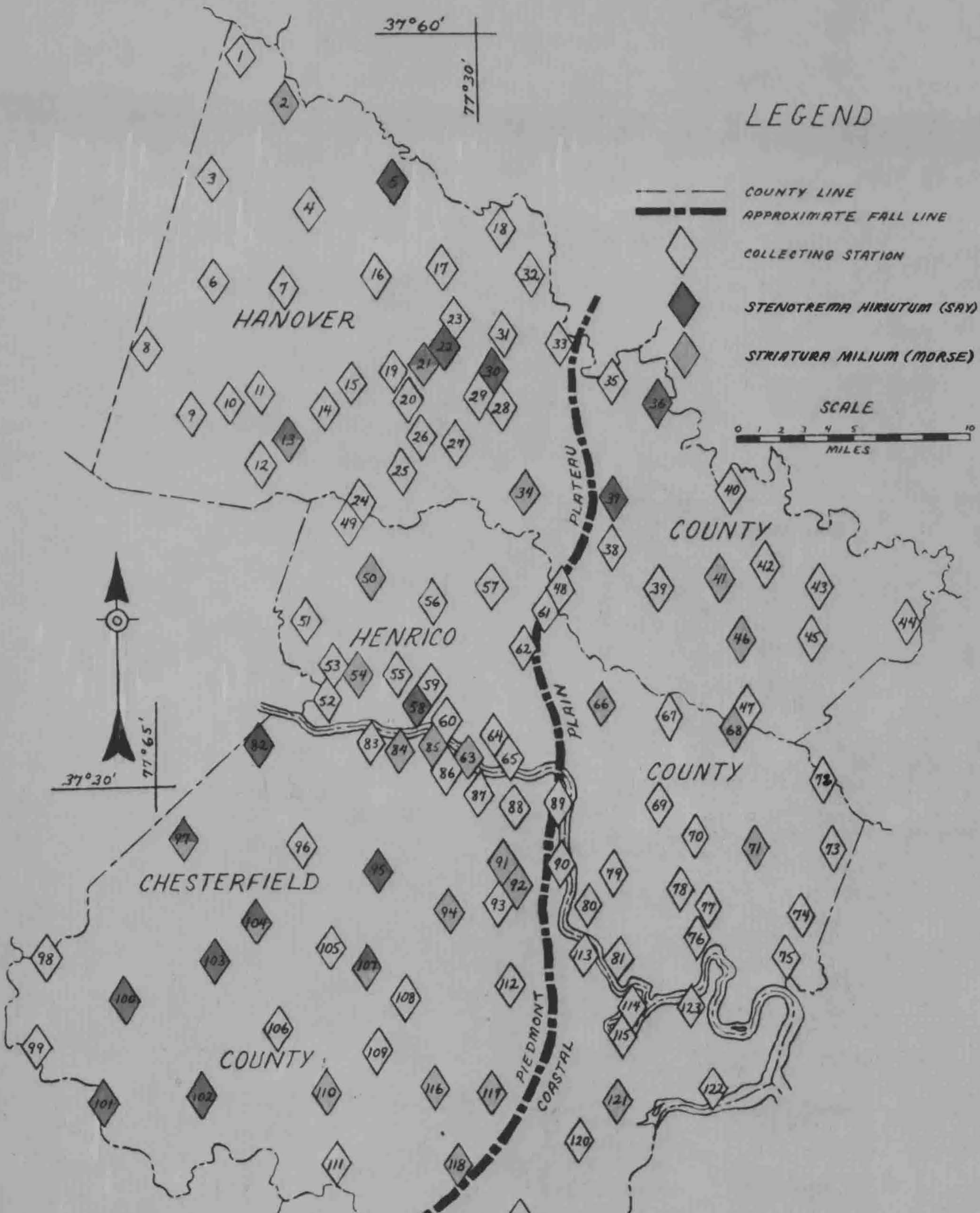
MAP XIII


37°60'
77°30'
LEGEND
COUNTY LINE
APPROXIMATE FALL LINE
COLLECTING STATION
PUPOIDES ALBILABRIS (ADAMS)
RETINELLA BURRINGTONI (PILSBRY)
SCALE
MILES
HANOVER
HENRICO
COUNTY
COUNTY
CHESTERFIELD
COUNTY
PLATEAU
PLAIN
PIEDMONT
COASTAL
37°30'
77°65'

MAP XIV

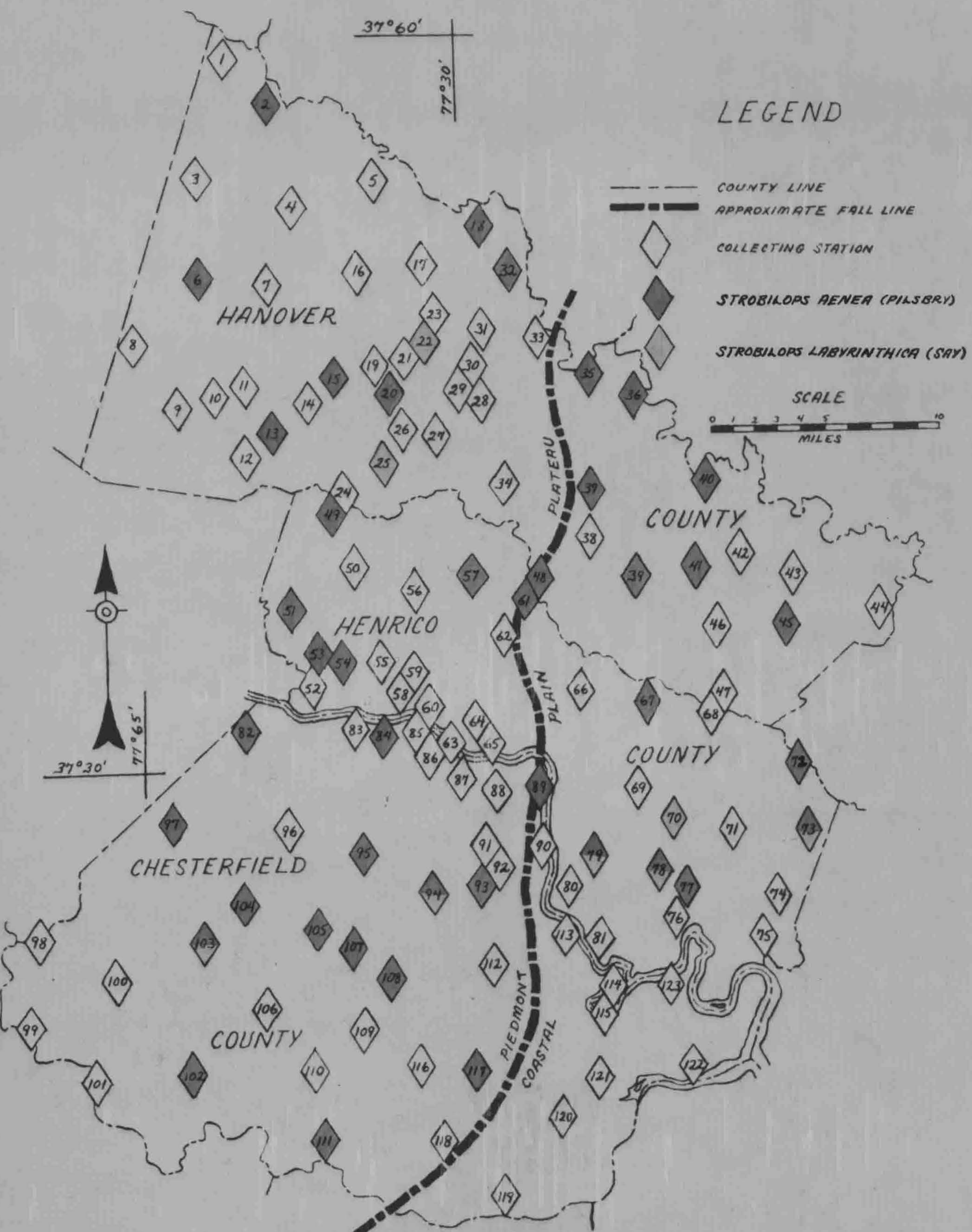

37°60'
77°30'
LEGEND
COUNTY LINE
APPROXIMATE FALL LINE
COLLECTING STATION
RETINELLA INDENTATA (SAY)
RETINELLA RHOADSI AUSTRINA BAKER
SCALE
0 1 2 3 4 5 10
MILES
HANOVER
COUNTY
HENRICO
COUNTY
CHESTERFIELD
COUNTY
PLATEAU
PLAIN
PIEDMONT
COASTAL
37°30'
77°65'

MAP XV



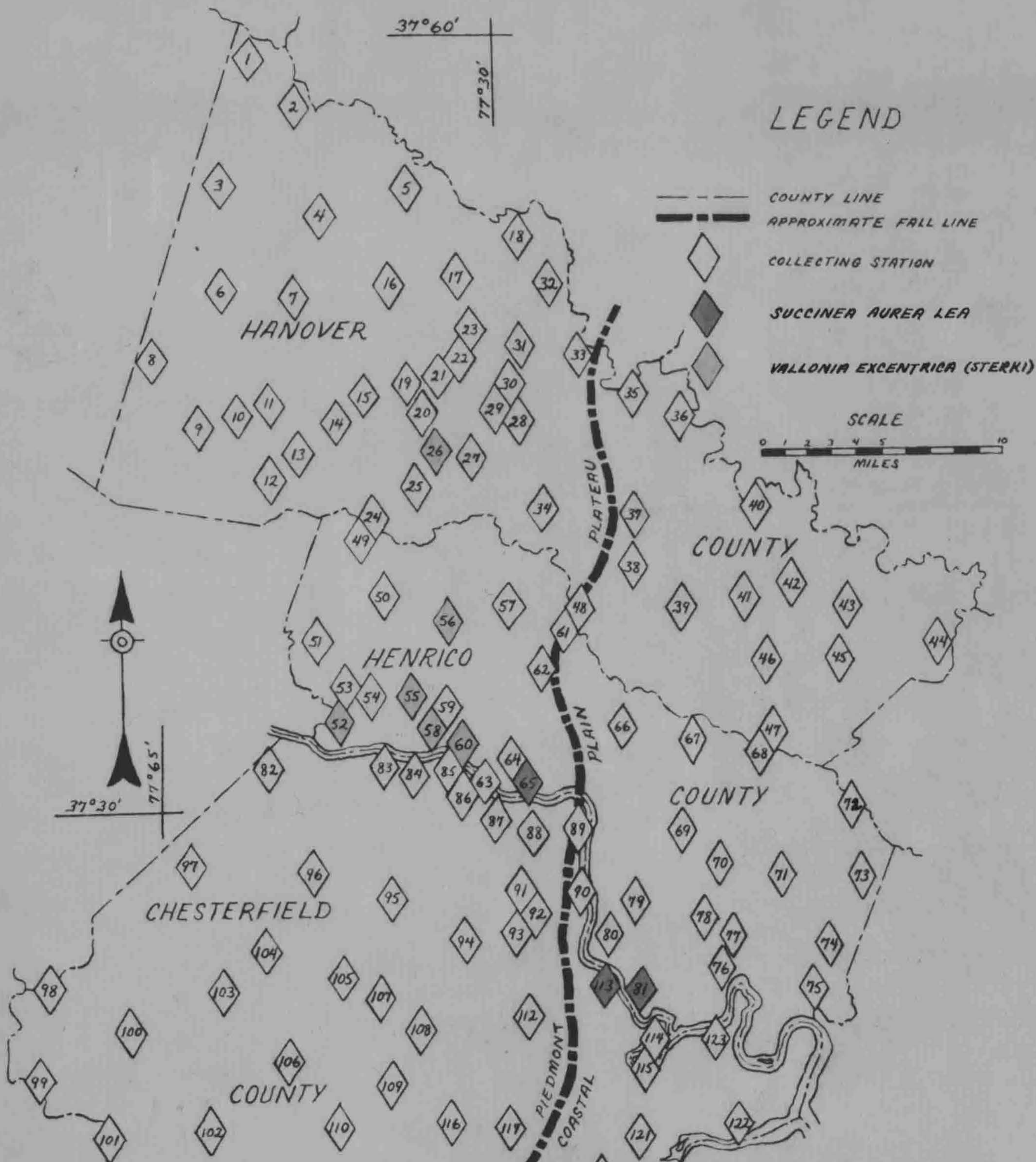
LEGEND
COUNTY LINE
APPROXIMATE FALL LINE
COLLECTING STATION
STENOTREMA HIRSUTUM (SAY)
STRIATURA MILIUM (MORSE)
SCALE
0 1 2 3 4 5 10
MILES
37°60'
77°30'
37°30'
77°65'
HANOVER
HENRICO
COUNTY
COUNTY
CHESTERFIELD
COUNTY
PIEDMONT
PLATEAU
COASTAL
PLAIN

MAP XVI



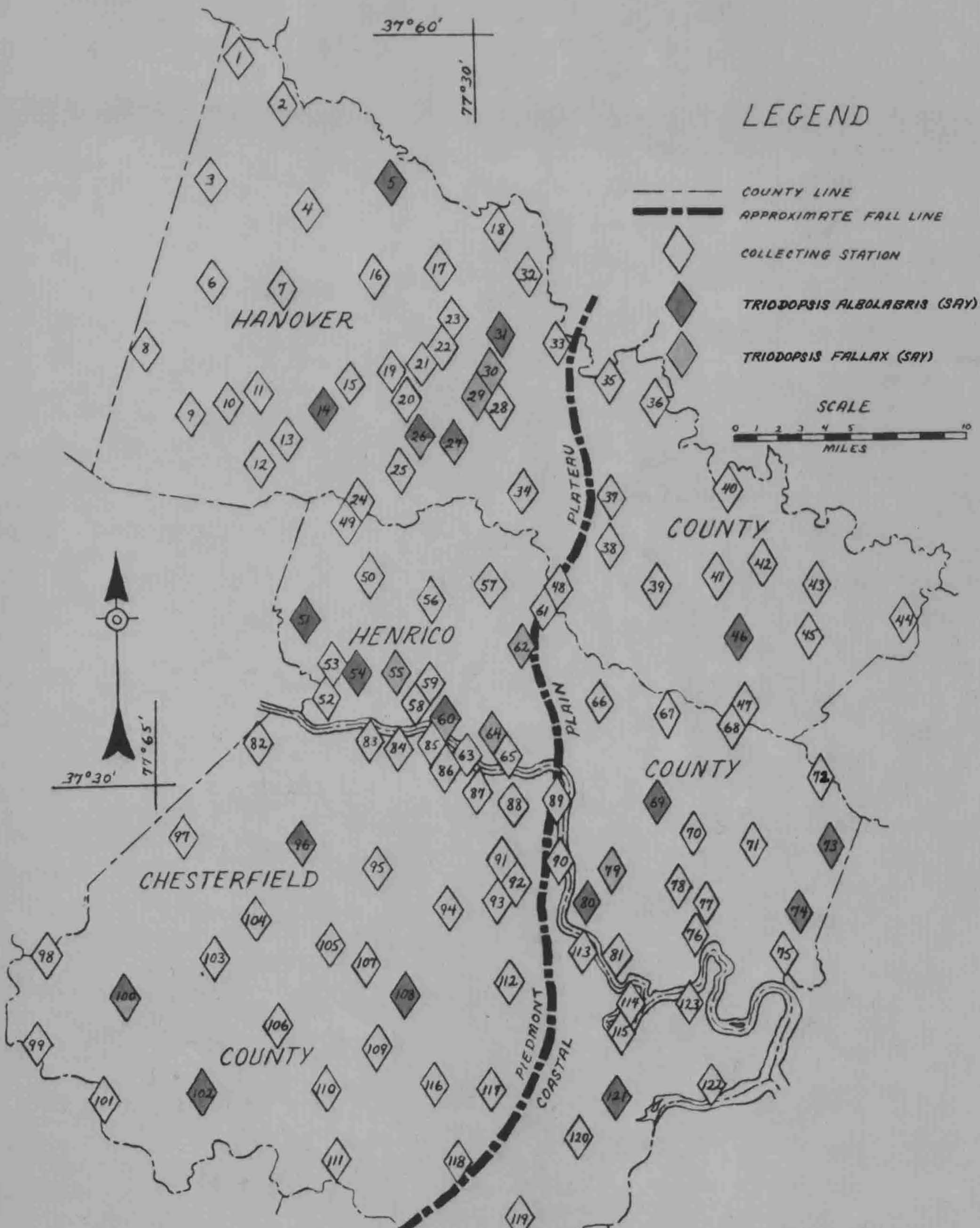
37°60'
77°30'
LEGEND
COUNTY LINE
APPROXIMATE FALL LINE
COLLECTING STATION
STROBILOPS AENEA (PILSBRY)
STROBILOPS LABYRINTHICA (SAY)
SCALE
MILES
HANOVER
COUNTY
HENRICO
COUNTY
CHESTERFIELD
COUNTY
PLATEAU
PLAIN
PIEDMONT
COASTAL
37°30'
77°65'

MAP XVII



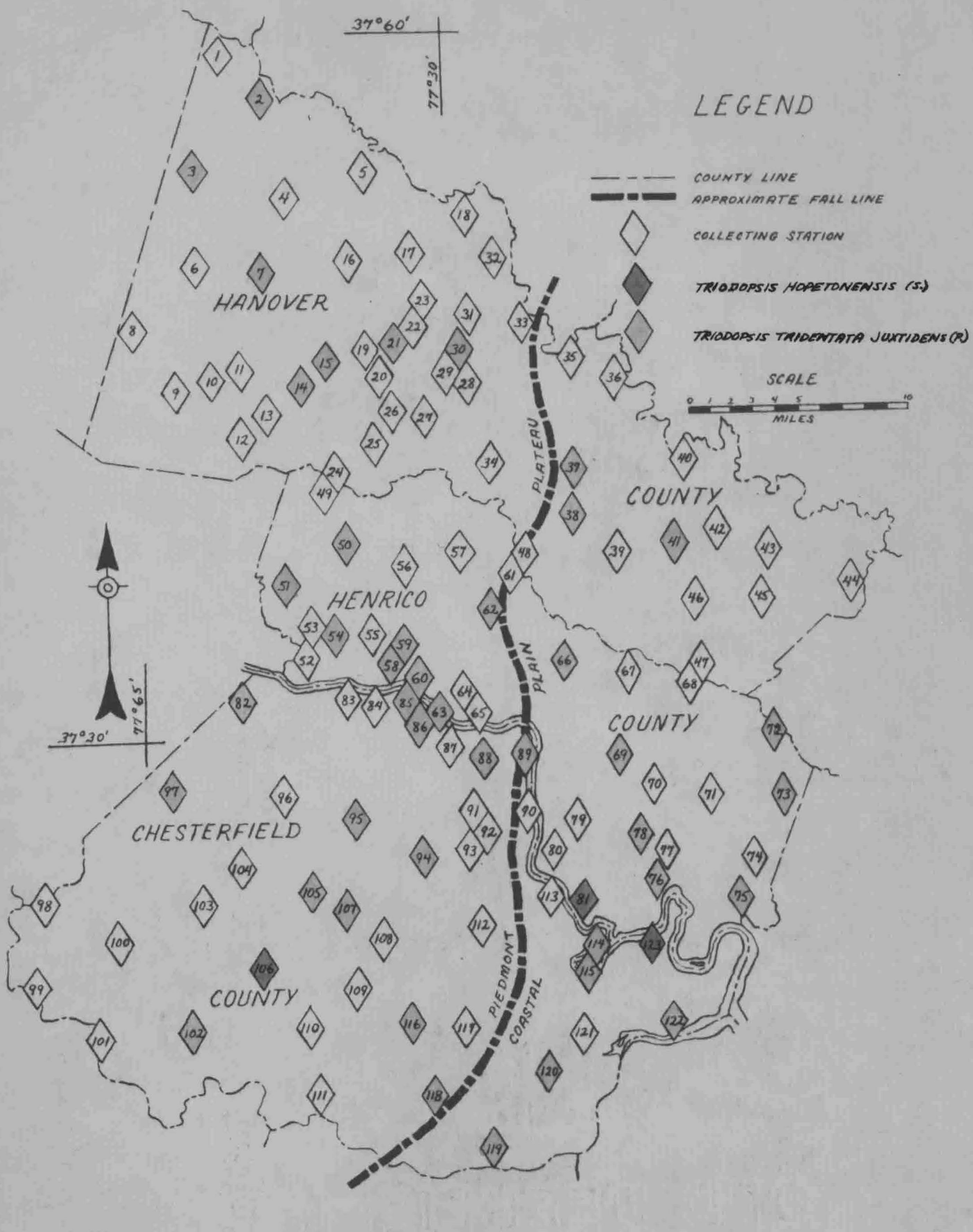
37°60'
77°30'
LEGEND
COUNTY LINE
APPROXIMATE FALL LINE
COLLECTING STATION
SUCCINEA AUREA LEA
VALLONIA EXCENTRICA (STERKI)
SCALE
0 1 2 3 4 5 10
MILES
HANOVER
HENRICO
COUNTY
COUNTY
CHESTERFIELD
COUNTY
PLATEAU
PLAIN
PIEDMONT
COASTAL
37°30'
77°65'

MAP XVIII

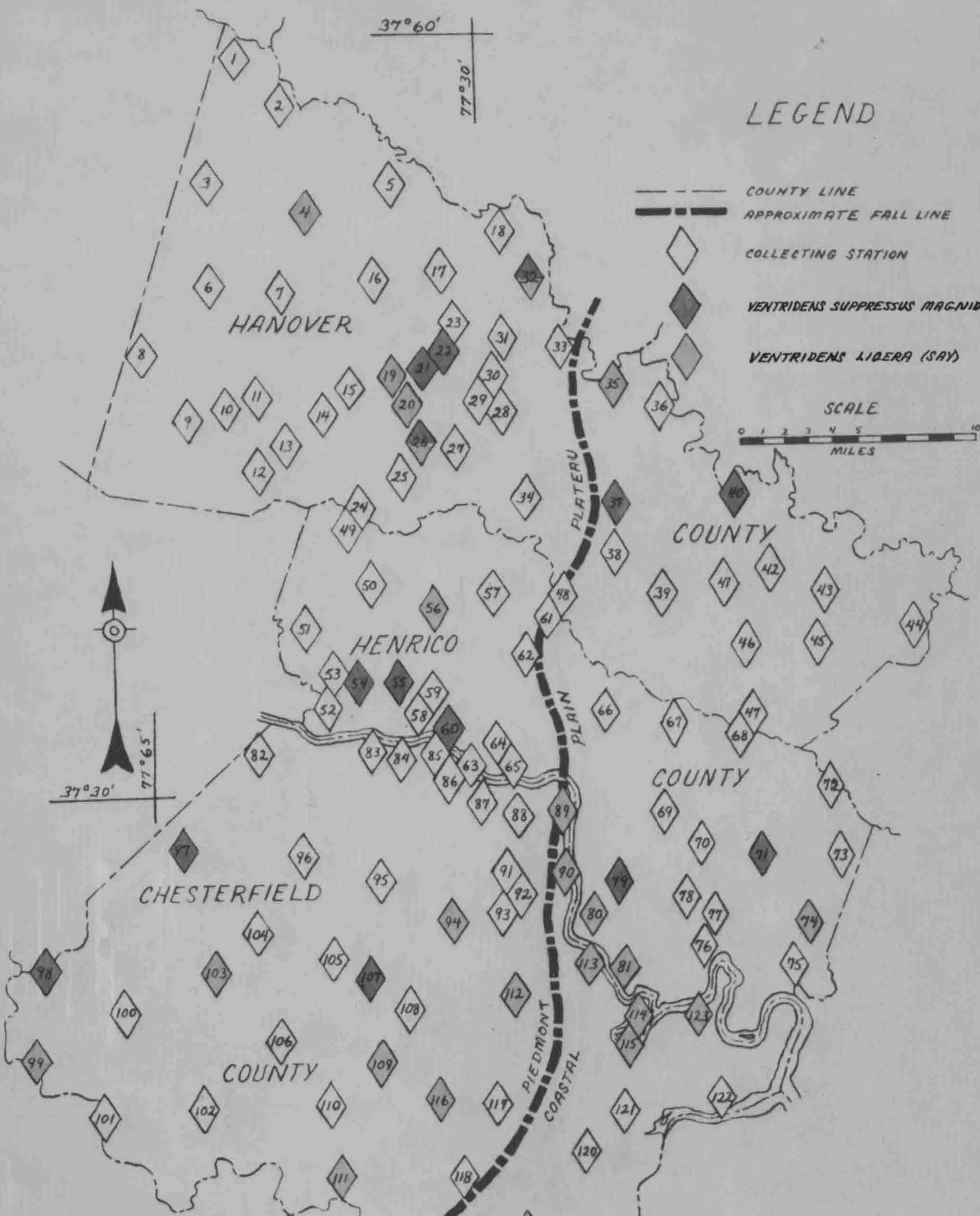


37°60′
77°30′
LEGEND
COUNTY LINE
APPROXIMATE FALL LINE
COLLECTING STATION
TRIODOPSIS ALBOLABRIS (SAY)
TRIODOPSIS FALLAX (SAY)
SCALE
MILES
HANOVER
COUNTY
HENRICO
COUNTY
CHESTERFIELD
COUNTY
PLATEAU
PLAIN
PIEDMONT
COASTAL
77°65′
37°30′

MAP XIX

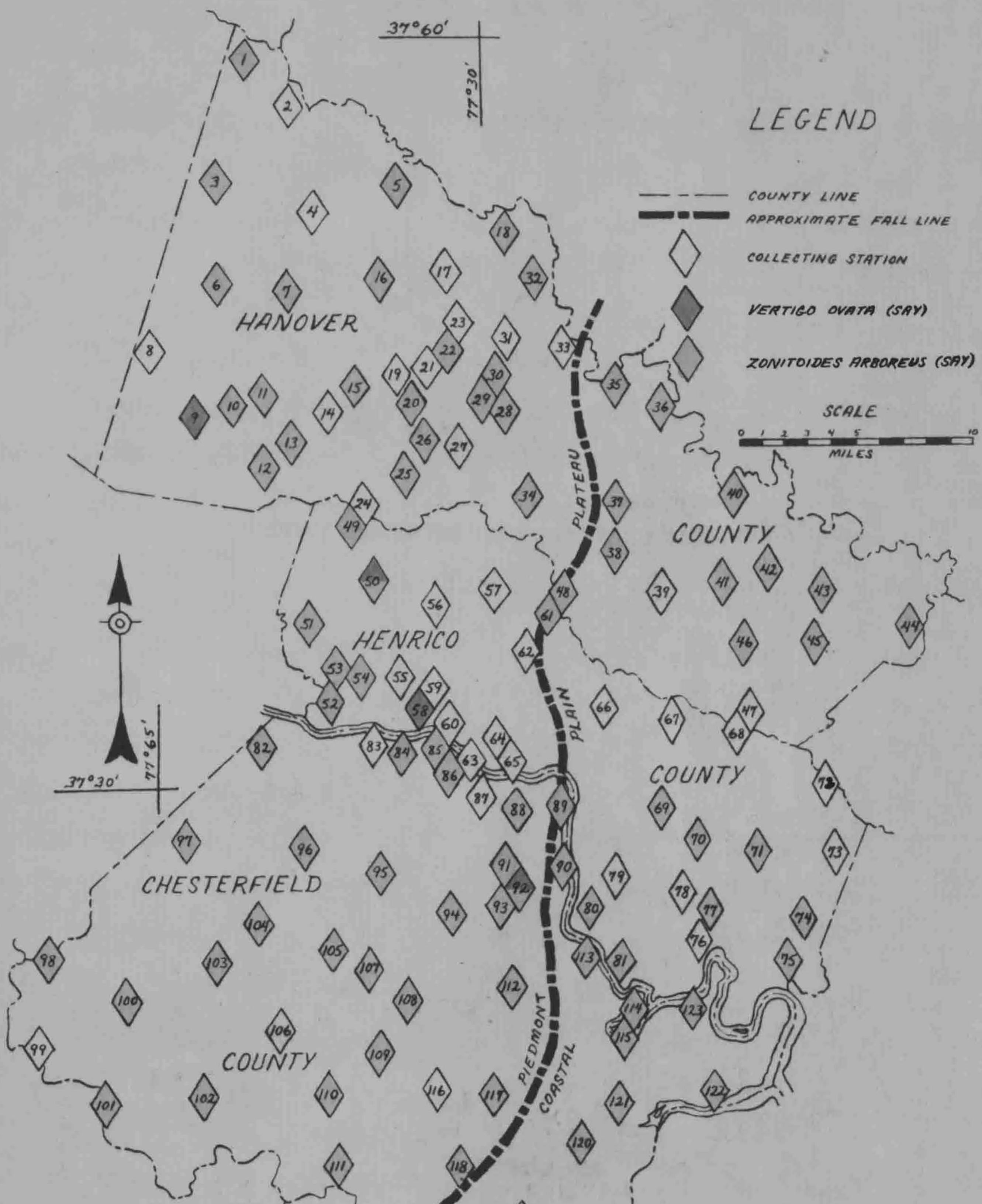

37°60'
77°30'
LEGEND
COUNTY LINE
APPROXIMATE FALL LINE
COLLECTING STATION
TRIODOPSIS HOPETONENSIS (S.)
TRIODOPSIS TRIDENTATA JUXTIDENS (R)
SCALE
0 1 2 3 4 5 10
MILES
HANOVER
COUNTY
HENRICO
COUNTY
CHESTERFIELD
COUNTY
PLATEAU
PLAIN
PIEDMONT
COASTAL
37°30'
77°65'

MAP XX



37°60'
77°30'
LEGEND
COUNTY LINE
APPROXIMATE FALL LINE
COLLECTING STATION
VENTRIDENS SUPPRESSUS MAGNIDENS P.
VENTRIDENS LIGERA (SAY)
SCALE
0 1 2 3 4 5 10
MILES
HANOVER
HENRICO
COUNTY
COUNTY
CHESTERFIELD
COUNTY
PLATEAU
PLAIN
PIEDMONT
COASTAL
37°30'
77°65'

MAP XXI


37°60'
77°30'
LEGEND
COUNTY LINE
APPROXIMATE FALL LINE
COLLECTING STATION
VERTIGO OVATA (SAY)
ZONITOIDES ARBOREUS (SAY)
SCALE
0 1 2 3 4 5 10
MILES
HANOVER
COUNTY
HENRICO
COUNTY
CHESTERFIELD
COUNTY
PLATEAU
PLAIN
PIEDMONT
COASTAL
37°30'
77°65'

A P P E N D I X H

FREQUENCY INDEXS AND FREQUENCY PERCENTAGES

FREQUENCY INDEXS AND PERCENTAGES

	Frequency Index*	Frequency Percentage	Frequency
Anguispira alternata angulata	22/123 =.179	17.9	occasional
Carychium exiguum	13/123 = .106	10.6	Occasional
Cionella lubrica morseana	1/123 =.008	.8	rare
Columella edentula	8/123 =.065	6.5	occasional
Euconulus chersinus	9/123 =.073	7.3	occasional
Euconulus fulvus	1/123 =.008	.8	rare
Gastrocopta armifera	1/123 =.008	.8	rare
Gastrocopta contracta	27/123 =.219	21.9	occasional
Gastrocopta pentodon	8/123 =.065	6.5	occasional
Gastrocopta procera mcclungi	3/123 =.025	2.5	rare
Haplotrema concavum	50/123 =.407	40.7	frequent
Hawaiia minuscula	30/123 =.244	24.4	occasional
Helicodiscus parallelus	80/123 =.650	65.0	common
Mesodon appressus sculptior	6/123 =.049	4.9	rare
Mesodon thyroidus	31/123 =.252	25.2	frequent
Punctum minutissimum	3/123 =.025	2.5	rare
Pupoides albilabris	3/123 =.025	2.5	rare
Retinella burringtoni	28/123 =.228	22.8	occasional
Retinella indentata	52/123 =.423	42.3	frequent
Retinella rhoadsi austrina	2/123 =.016	1.6	rare
Stenotrema hirsutum	17/123 =.138	13.8	occasional
Striatura milium	25/123 =.203	20.3	occasional

---

*Frequency index = $\frac{\text{number of samples in which the species is present}}{\text{total number of samples examined}}$

q.v. Dice, 1952, pp.43-44

	Frequency Index	Frequency Percentage	Frequency
Strobilops aenea	42/123 =.341	34.1	frequent
Strobilops labyrinthica	8/123 =.065	6.5	occasional
Succinea aurea	3/123 =.025	2.5	rare
Triodopsis albolabris	18/123 =.146	14.6	occasional
Triodopsis fallax	11/123 =.089	8.9	occasional
Triodopsis hopetonensis	3/123 =.025	2.5	rare
Triodopsis tridentata juxtidens	43/123 =.350	35.0	frequent
Vallonia excentrica	6/123 =.049	4.9	rare
Ventridens ligera	24/123 =.195	19.5	occasional
Ventridens suppressus magnidens	14/123 =.114	11.4	occasional
Vertigo ovata	4/123 =.033	3.3	rare
Zonitoides arboreus	86/123 =.699	69.9	common

A P P E N D I X   I

PLANT ASSOCIATIONS

SPECIES	PLANT ASSOCIATION																					
	OAK *Quercus*	OAK-BEECH *Quercus-Fagus*	OAK-BIRCH *Quercus-Betula*	OAK-ELM *Quercus-Ulmus*	OAK-MAPLE *Quercus-Acer*	OAK-PINE *Quercus-Pinus*	OAK-POPULAR *Quercus-Liriodendron*	OAK-SWEETGUM *Quercus-Liquidambar*	OAK-SYCAMORE *Quercus-Platanus*	ELM-BEECH *Ulmus-Fagus*	ELM-BIRCH *Ulmus-Betula*	ELM-HICKORY *Ulmus-Carya*	ELM-SYCAMORE *Ulmus-Platanus*	BEECH-BIRCH *Fagus-Betula*	BEECH-PINE *Fagus-Pinus*	BEECH-SYCAMORE *Fagus-Platanus*	BIRCH-POPULAR *Betula-Liriodendron*	BIRCH-SYCAMORE *Betula-Platanus*	MAPLE *Acer*	MAPLE-SWEETGUM *Acer-Liquidambar*	SYCAMORE-WILLOW *Platanus-Salix*	WILLOW *Salix*
Anguispira alternata angulata	R*	R	R	O					R	R		R										
Carychium exiguum	R			R		R	R		R													
Cionella lubrica morseana																						
Columella edentula						R														R		
Euconulus chersinus	R	R	R				R							R								
Euconulus fulvus																						
Gastrocopta armifera																						
Gastrocopta contracta	O		R	R		R	R		O									R	R			
Gastrocopta pentodon				R			R		R													
Gastrocopta procera mcclungi																						
Haplotrema concavum	O	O	R	R	R	O	O	R	O			R	R			R		R	O	R	R	O
Hawaiia minuscula	R			R	R				O									R	R		R	R
Helicodiscus parallelus	O	O	O	O	F	C	F	R	O	O	R	R	R	R	R	R	R	R	R	R	O	R
Mesodon appressus sculptior							R		R												O	O
Mesodon thyroidus	O	O	O		O	O	F		R										R		R	R
Punctum minutissimum				R		R																
Pupoides albilabris					O																	
Retinella burringtoni	R	O	R	R	R	O	O	R	O	R									R			
Retinella indentata	O	O	R	R	O	O	C		O	R			R	R	R	O		R		R	R	
Retinella rhoadsi austrina						R															R	
Stenotrema hirsutum	O	R	R	R		O	R	R	R			R										
Striatura milium	O			R	R	O	O		O											R		
Strobilops aenea	O	O	O	O		F	O		O	R		R		R		R		R	R			
Strobilops labyrinthica					R	R												R				
Succinea aurea																						
Triodopsis albolabris	R	R			O	R	R															
Triodopsis fallax	R				O	R							R									
Triodopsis hopetonensis	R																				R	R
Triodopsis tridentata juxtidens	O	O	R		O	O	O		O				O						R		R	
Vallonia excentrica																R						
Ventridens ligera		R	R		R	O			R					R		R			R		R	R
Ventridens suppressus magnidens	O	R			R	O			R					R						R		
Vertigo ovata					R		R															
Zonitoides arboreus	O	O	O	O	O	C	F	R	O	R	R	R	R	R		R	R	R	R	R	O	R

* THE SYMBOLS "C", "F", "O", AND "R", ARE USED TO REPRESENT COMMON, FREQUENT, OCCASIONAL, AND RARE OCCURRENCE.

A P P E N D I X J

SNAILS FOUND IN RELATION TO STATIONS WHERE SOIL SAMPLES WERE TAKEN

SPECIES AND SUBSPECIES FOUND IN RELATION TO SOIL SAMPLES

Station
Number

2. Carychium exiguum (Say)....................................1
Columella edentula (Draparnaud)..............................1
Hawaiia minuscula (Binney)...................................3
Helicodiscus parallelus (Say)....... 6
Retinella burringtoni (Pilsbry)..............................2
Retinella indentata (Say)....................................2
Striatura milium (Morse).....................................1
Strobilops aenea (Pilsbry)..... 2
Triodopsis tridentata juxtidens (Pilsbry)...................4

4. Haplotrema concavum(Say)....................................1
Helicodiscus parallelus (Say)................................3
Mesodon thyroidus (Say)......................................2
Retinella indentata (Say)....................................2
Ventridens ligera (Say)......................................5

10. Haplotrema concavum (Say)..................................1
Zonitoides arboreus (Say)....................................4

13. Anguispira alternata angulata (Ferussac)...................1
Carychium exiguum (Say).....................................12
Gastrocopta contracta (Say).................................26
Gastrocopta pentodon (Say) 5
Haplotrema concavum (Say)...................................10
Hawaiia minuscula (Binney)..................................28
Helicodiscus parallelus (Say)................................ 3
Punctum minutissimum (Lea)..... 2
Retinella burringtoni (Pilsbry)..............................13
Retinella indentata (Say)....................................21
Stenotrema hirsutum (Say)....... 1
Striatura milium (Morse)..................................... 1
Strobilops aenea (Pilsbry)................................... 6
Zonitoides arboreus (Say).................................... 6

15. Carychium exiguum (Say)................................... 4
Gastrocopta contracta (Say)........... 1
Gastrocopta pentodon (Say)................................... 1
Hawaiia Minuscula (Binney)................................... 2
Helicodiscus parallelus (Say)................................11
Retinella burringtoni (Pilsbry).............................. 3
Retinella indentata (Say)....................................12
Strobilops aenea (Pilsbry).................................. 3
Triodopsis tridentata juxtidens (Pilsbry)................... 5
Zonitoides arboreus (Say).................................... 2

Station
Number

18. _Helicodiscus parallelus_ (Say)............................ 5
Retinella burringtoni (Pilsbry)........................ 1
Retinella indentata (Say)............................ 2
Strobilops aenea (Pilsbry)............................1
Zonitoides arboreus (Say)..............................2

20. _Helicodiscus parallelus_ (Say)............................1
Strobilops aenea (Pilsbry)............................28
Ventridens ligera (Say)................................ 1
Zonitoides arboreus (Say)..............................10

24. _Helicodiscus parallelus_ (Say)........................... 1

26. _Gastrocopta armifera_ (Say).............................14
Hawaiia minuscula (Binney)............................11
Triodopsis fallax (Say) 8
Vallonia excentrica (Sterki)...........................19
Ventridens suppressus magnidens (Pilsbry)................ 6
Zonitoides arboreus (Say)..............................19

35. _Haplotrema concavum_ (Say)............................. 2
Helicodiscus parallelus (Say).......................... 2
Retinella indentata (Say)............................. 1
Strobilops aenea (Pilsbry) 1
Ventridens ligera (Say)............................... 3
Zonitoides arboreus (Say)............................. 2

36. _Anguispira alternata angulata_ (Ferussac)................ 2
Haplotrema concavum (Say)............................. 1
Helicodiscus parallelus (Say)......................... 4
Stenotrema hirsutum (Say)..... 2
Strobilops aenea (Pilsbry)............................ 2
Zonitoides arboreus (Say)............................. 5

37. _Euconulus chersinus_ (Say)............................. 1
Retinella burringtoni (Pilsbry)....... 1
Strobilops aenea (Pilsbry)....... 7
Ventridens suppressus madnidens (Pilsbry) 4
Zonitoides arboreus (Say)............................. 9

41. _Gastrocopta contracta_ (Say) 1
Helicodiscus parallelus (Say)..........................10
Retinella indentata (Say)............................. 1
Striatura milium (Morse).............................. 1
Strobilops aenea (Pilsbry)............................ 6
Triodopsis tridentata juxtidens (Pilsbry)................ 1
Zonitoides arboreus (Say)............................. 3

Station
Number

42\. *Helicodiscus parallelus* (Say) 3
Zonitoides arboreus (Say) 8

43\. *Helicodiscus parallelus* (Say) 2
Retinella indentata (Say) 1
Zonitoides arboreus (Say) 1

63\. *Gastrocopta contracta* (Say) 6
Haplotrema concavum (Say) 1
Mesodon thyriodus (Say) 4
Retinella burringtoni (Pilsbry) 7
Retinella indentata (Say) 10
Striatura milium (Morse) 1
Triodopsis tridentata juxtidens (Pilsbry) 5

71\. *Columella edentula* (Draparnaud), ... 3
Haplotrema concavum (Say) 1
Helicodisvus parallelus (Say) 17
Retinella indentata (Say) 1
Striatuta milium (Morse) 1
Ventridens suppressus magnidens (Pilsbry) 25
Zonitoides arboreus (Say) 13

77\. *Gastrocopta contracta* (Say) ,,, ... 16
Hawaiia minuscula (Binney) 1
Strobilops aenea (Pilsbry) 19
Zonitoides arboreus (Say) 30

79\. *Haplotrema concavum* (Say) 2
Hawaiia minuscula (Binney) 5
Helicodiscus parallelus (Say) 3
Retinella indentata (Say) 1
Strobilops aenea (Pilsbry) 1
Strobilops labyrinthica (Say) 1
Triodopsis fallax (Say) 26
Ventridens suppressus magnidens (Pilsbry) 4

81\. *Haplotrema concavum* (Say) 3
Hawaiia minuscula (Binney) 1
Helicodiscus parallelus (Say) 2
Mesodon appressus sculptior (Chadwick) 2
Mesodon thyroidus (Say) 3
Triodopsis hopetonensis (Shuttleworth) 1
Ventridens ligera (Say) 5
Zonitoides arboreus (Say) 14

Station Number		
84.	Gastrocopta contracta (Say)	17
	Haplotrema concavum (Say)	3
	Hawaiia minuscula (Binney)	2
	Helicodiscus parallelus (Say)	1
	Mesodon appressus sculptior (Chadwick)	3
	Retinella burringtoni (Pilsbry)	8
	Retinella indentata (Say)	8
	Striatura milium (Morse)	1
	Strobilops aenea (Pilsbry	4
	Zonitoides arboreus (Say)	49
85.	Carychium exiguum (Say)	7
	Cionella lubrica morseana (Doherty)	5
	Euconulus chersinus (Say)	2
	Haplotrema concavum (Say)	17
	Helicodiscus parallelus (Say)	3
	Mesodon appressus sculptior (Chadwick)	4
	Mesodon thyroidus (Say)	2
	Retinella indentata (Say)	3
	Striatura milium (Morse)	1
	Triodopsis tridentata juxtidens (Pilsbry)	15
	Zonitoides arboreus (Say)	4
86.	Haplotrema concavum (Say)	2
	Helicodiscus parallelus (Say)	3
	Triodopsis tridentata juxtidens (Pilsbry)	2
	Zonitoides arboreus (Say)	5
88.	Haplotrema concavum (Say)	10
	Hawaiia minuscula (Binney)	1
	Helicodiscus parallelus (Say)	6
	Mesodon appressus sculptior (Chadwick)	8
	Retinella indentata (Say)	2
	Retinella rhoadsi austrina (Baker)	1
	Triodopsis tridentata juxtidens (Pilsbry)	8
	Zonitoides arboreus (Say)	6
89.	Gastrocopta contracta (Say)	3
	Haplotrema concavum (Say)	23
	Hawaiia minuscula (Binney)	6
	Helicodiscus parallelus (Say)	1
	Mesodon thyroidus (Say)	11
	Retinella burringtoni (Pilsbry)	1
	Strobilops aenea (Pilsbry)	8
	Triodopsis tridentata juxtidens (Pilsbry)	7
	Ventridens ligera (Say)	15
	Zonitoides arboreus (Say)	81

LIBRARY
UNIVERSITY OF RICHMOND
VIRGINIA

Station
Number

91. Helicodiscus parallelus (Say)........................... 1
Mesodon thyroidus (Say)................................ 1
Retinella indentata (Say).............................. 3
Striatura milium (Morse)............................... 2
Zonitoides arboreus (Say).............................. 3

92. Haplotrema concavum (Say).............................. 1
Helicodiscus parallelus (Say).......................... 3
Retinella burringtoni (Pilsbry)........................ 1
Retinella indentata (Say).............................. 2
Striatura milium (Morse)....... 1
Vertigo ovata (Say)....................................1
Zonitoides arboreus (Say)..............................4

93. Mesodon thyroidus (Say) 2
Retinella indentata (Say)..............................1
Strobilops aenea (Pilsbry)........... 1
Zonitoides arboreus (Say)..............................4

94. Gastrocopta contracta (Say)............................1
Helicodiscus parallelus (Say)..........................2
Punctum minutissimum (Lea).............................1
Retinella indentata (Say)..............................3
Striatura milium (Morse)...............................4
Strobilops aenea (Pilsbry).............................1
Strobilops labyrinthica (Say)..........................2
Triodopsis tridentata juxtidens (Pilsbry)..............4
Ventridens ligera (Say)................................1
Zonitoides arboreus (Say)..............................12

97. Carychium exiguum (Say)................................ 6
Columella edentula (Draparnaud)........................ 1
Euconulus chersinus (Say)............. 1
Haplotrema concavum (Say).............................. 2
Helicodiscus parallelus (Say).......................... 5
Mesodon thyroidus (Say)................................ 3
Retinella burringtoni (Pilsbry)........................ 2
Stenotrema hirsutum (Say).............................. 1
Striatura milium (Morse)............................... 1
Strobilops aenea (Pilsbry)............................. 2
Triodopsis tridentata juxtidens (Pilsbry).............. 3
Ventridens suppressus magnidens (Pilsbry).............. 1
Zonitoides arboreus (Say).............................. 2

105. Anguispira alternata angulata (Ferussac).............. 1
Helicodiscus parallelus (Say).... 4
Retinella burringtoni (Pilsbry)........................ 2
Retinella indentata (Say).............................. 2
Strobilops aenea (Pilsbry)............................. 1
Triodopsis tridentata juxtidens (Pilsbry).............. 1
Zonitoides arboreus (Say)..............................22

Station
Number

107. *Carychium exiguum* (Say) 5
Euconulus chersinus (Say)........................... 3
Gastrocopta contracta (Say)......................... 3
Haplotrema concavum (Say)........................... 2
Hawaiia minuscula (Binney) 1
Helicodiscus parallelus (Say)....................... 7
Punctum minutissimum (Lea).......... 2
Retinella burringtoni (Pilsbry)....................14
Retinella indentata (Say)........................... 8
Stenotrema hirsutum (Say)...........................3
Striatura milium (Morse)............................4
Strobilops aenea (Pilsbry)..........................3
Triodopsis tridentata juxtidens (Pilsbry)...........4
Ventridens suppressus magnidens (Pilsbry)...........1
Zonitoides arboreus (Say)...........................2

A P P E N D I X K

FREQUENCY OF SNAILS FROM STATIONS WHERE SOIL SAMPLES WERE TAKEN

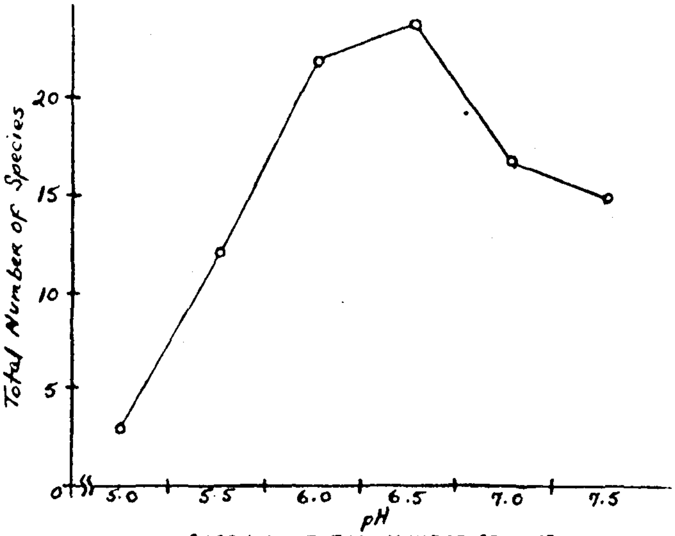
SPECIES	NUMBER OF STATIONS																																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Cionella lubrica morseana	X																																	
Gastrocopta armifera	X																																	
Retinella rhoadsi austrina	X																																	
Triodopsis hopetonensis	X																																	
Vallonia excentrica	X																																	
Vertigo ovata	X																																	
Strobilops labyrinthica		X																																
Triodopsis albolabris		X																																
Triodopsis fallax		X																																
Columella edentula			X																															
Gastrocopta pentodon			X																															
Punctum minutissimum			X																															
Euconulus chersinus				X																														
Mesodon appressus sculptior				X																														
Stenotrema hirsutum				X																														
Anguispira alternata angulata					X																													
Carychium exiguum						X																												
Ventridens ligera						X																												
Ventridens suppressus magnidens							X																											
Mesodon thyroidus								X																										
Gastrocopta contracta									X																									
Hawaiia minuscula											X																							
Retinella burringtoni													X																					
Striatura milium														X																				
Triodopsis tridentata juxtidens																X																		
Haplotrema concavum																	X																	
Strobilops aenea																							X											
Retinella indentata																								X										
Helicodiscus parallelus																																X		
Zonitoides arboreus																																		X

TOTAL NUMBER OF STATIONS = 41

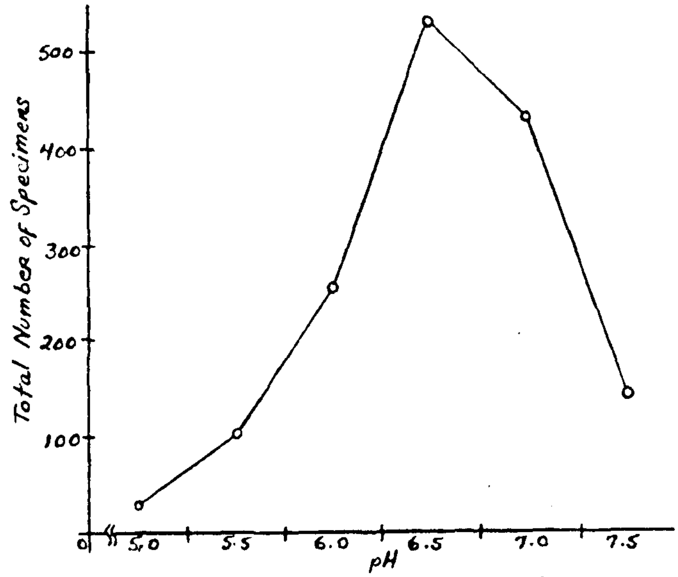
A P P E N D I X L

TABLE AND GRAPHS OF FREQUENCIES OF SNAILS IN RELATION TO pH, CALCIUM, MAGNESIUM, PHOSPHORUS, POTASSIUM, AND ORGANIC MATTER

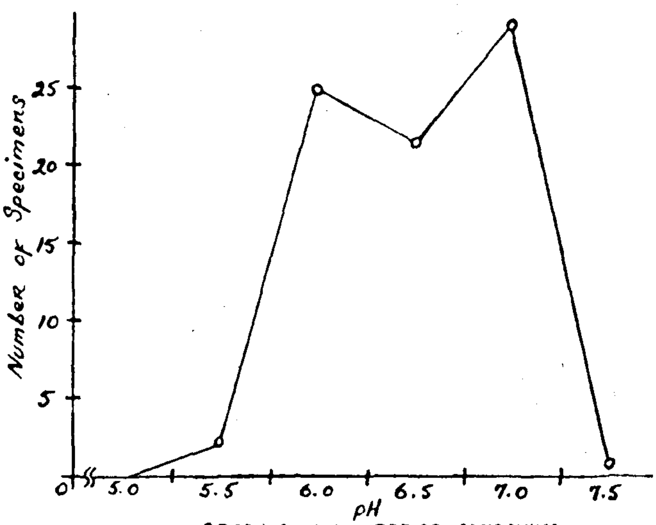
SPECIES	NUMBER OF SPECIMENS	pH						CALCIUM CaO				MAGNESIUM MgO				PHOSPHORUS P_2O_5				POTASSIUM K_2O				ORGANIC MATTER				NUMBER OF STATIONS
								L	M	H	VH	L	M	H	VH	L	M	H	VH	L	M	H	VH	L	M	H	VH	
		4.8 - 5.2	5.3 - 5.7	5.8 - 6.2	6.3 - 6.7	6.8 - 7.2	7.3 - 7.7	0.000-0.018 %	0.019-0.044 %	0.045-0.074 %	0.075+ %	0.000-0.002 %	0.003-0.008 %	0.009-0.017 %	0.018+ %	0.000-0.001 %	0.002-0.004 %	0.005-0.012 %	0.013+ %	0.000-0.003 %	0.004-0.007 %	0.008-0.011 %	0.012+ %	0.0-0.9 %	1.0-1.9 %	2.0-2.9 %	3.0+ %	
Anguispira alternata anguleta	42		4		35	1	2				42		34	3	5		40	1	1			34	8				42	5
Carychium exiguum	35			17	18					5	30			11	24	7	12	16				18	17				35	6
Cionella lubrica morseana	5			5							5				5	5						5					5	1
Columella edentula	5		3	1	1						5			4	1		5					4	1				5	3
Euconulus chersinus	7			3	4					3	4			4	3	2	5					6	1				7	4
Gastrocopta armifera	14						14				14				14				14				14	14				1
Gastrocopta contracta	74			1	30	42	1			4	70			20	54	18	28	28			1	10	63				74	9
Gastrocopta pentodon	7			1	6						7				7		1	6					7				7	3
Haplotrema concavum	82		4	25	23	29	1			6	76		2	14	66	22	38	12	10		4	27	51				82	17
Hawaiia minuscula	61			3	33	14	11			1	60			8	53	2	12	35	12		5	1	55			11	50	11
Helicodiscus parallelus	144	5	28	32	53	9	17		3	27	114		8	64	72	17	91	25	11		20	53	71			3	141	32
Mesodon appressus sculptior	17			6	8	3					17			2	15	7	2		8			4	13				17	4
Mesodon thyroidus	28		2	11		15				5	23			9	19	2	26				1	13	14				28	8
Punctum minutissimum	5				5					3	2			3	2		2	3				3	2				5	3
Retinella burringtoni	56		1	6	31	18				16	40			20	36	8	30	16	2			25	31				56	13
Retinella indentata	90		7	20	40	21	2		1	19	70		2	25	63	12	36	38	4		6	32	52			1	89	24
Retinella rhoadsi austrina	1				1						1				1				1				1				1	1
Stenotrema hirsutum	7			1	4		2			3	4			6	1		6	1				4	3				7	4
Striatura milium	21		1	5	11	2	2		1	11	9		1	14	6	3	12	6			4	13	4			1	20	14
Strobilops aenea	147	10	2	19	75	33	8		2	7	138		2	79	66	10	97	11	29		9	20	118			2	145	23
Strobilops labyrinthica	3				2	1				1	2			3				3			1	2					3	2
Triodopsis albolabris	2			1	1						1		1		1		2				1		1			1	1	2
Triodopsis fallax	34					26	8				34			26	8			26	8		26		8			8	26	2
Triodopsis hopetonensis	1			1							1			1			1						1				1	1
Triodopsis tridentata juxtidens	74			28	26	13	7		3	10	61		4	18	52	18	31	16	9		4	29	41		1	2	71	16
Vallonia excentrica	19						19				19				19				19				19	19				1
Ventridens suppressus magnidens	42		25	2	5	4	6		1	1	40		1	31	10		32	4	6		5	30	7			7	35	7
Ventridens ligera	30		8	5	2	15				6	24			10	20		28	1	1			9	21				30	6
Vertigo ovata	1				1					1				1			1					1					1	1
Zonitoides arboreus	425	14	17	59	115	182	38		1	52	372		16	156	253	61	268	39	57		12	81	332			20	405	34
TOTAL SPECIMENS	1479	29	102	252	530	428	138	0	13	181	1285	0	71	532	876	194	806	287	192	0	99	424	956	0	1	89	1389	1479
TOTAL SPECIES	30	3	12	22	24	17	15	0	8	19	29	0	10	24	27	15	24	19	16	0	14	23	27	0	1	12	28	30
TOTAL NUMBER STATIONS																												41



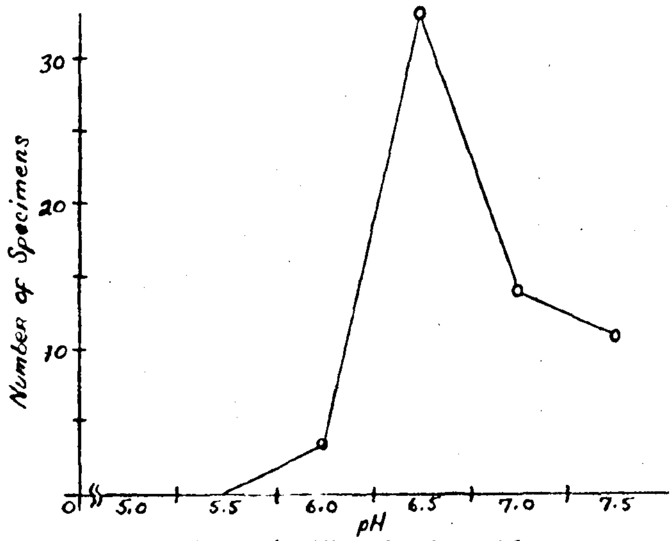
GRAPH 1. TOTAL NUMBER SPECIES



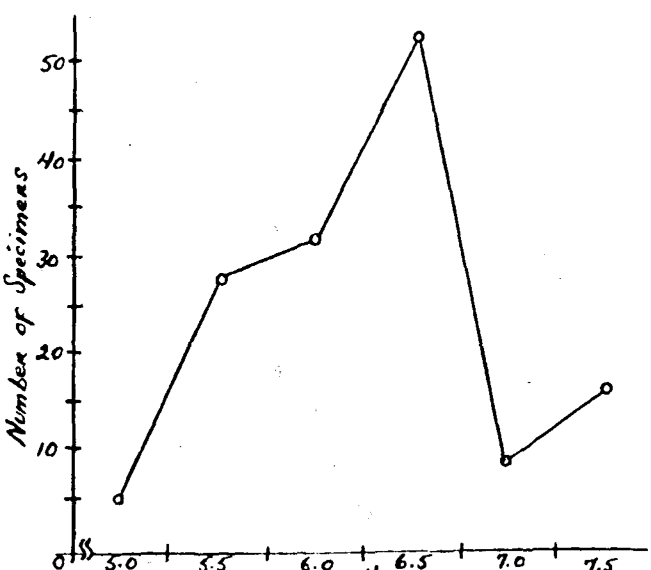
GRAPH 2. TOTAL NUMBER SPECIMENS



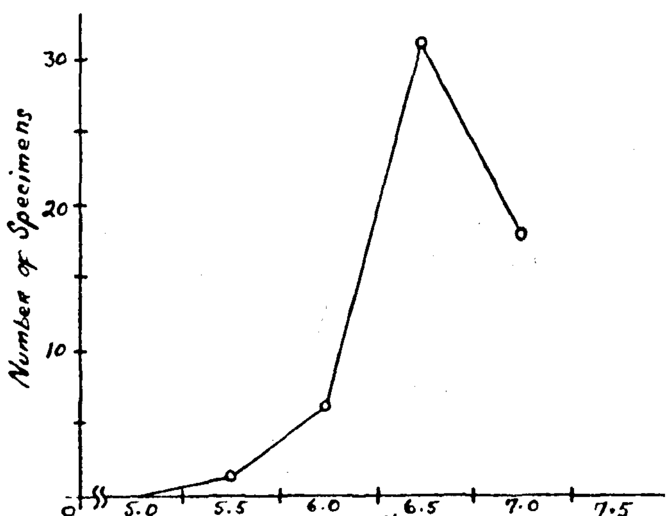
GRAPH 3. HAPLOTREMA CONCAVUM



GRAPH 4. HAWAIIA MINUSCULA

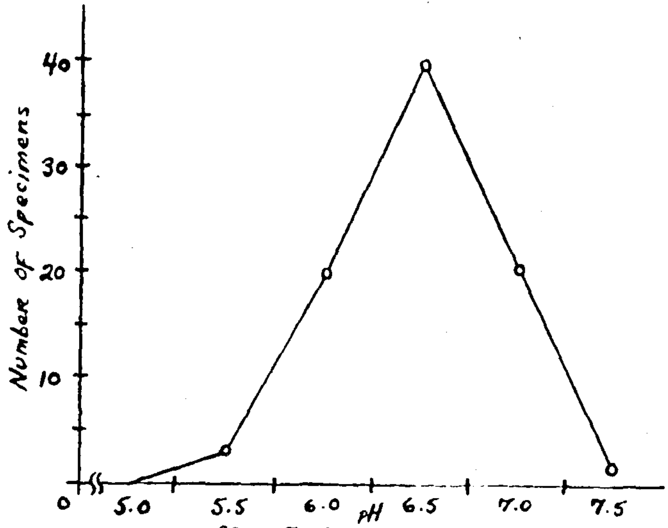


GRAPH 5. HELICODISCUS PARALLELUS

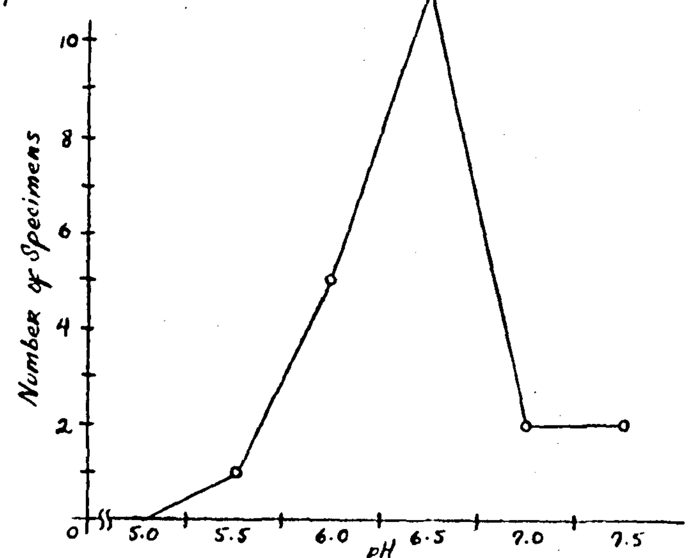


GRAPH 6. RETINELLA BURRINGTONI

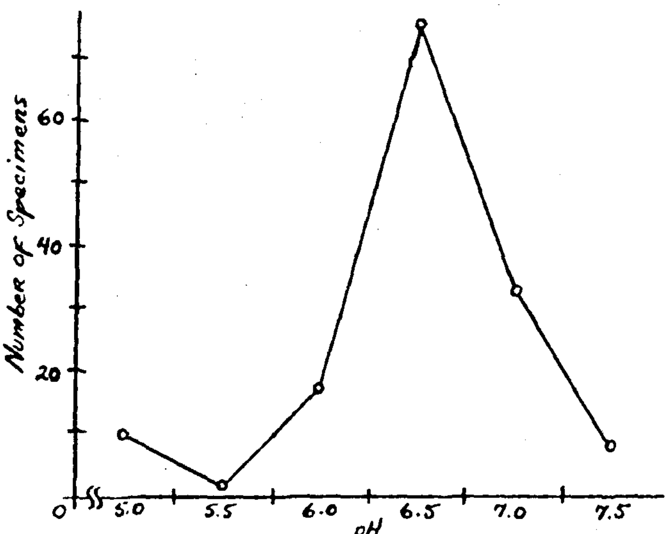
pH



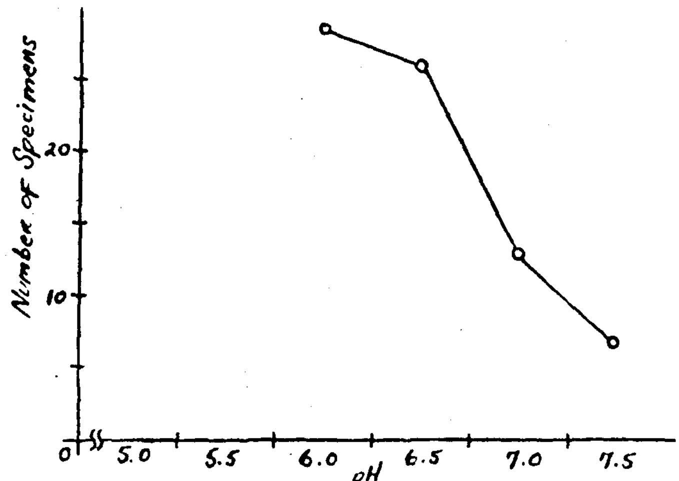
GRAPH 7. RETINELLA INDENTATA



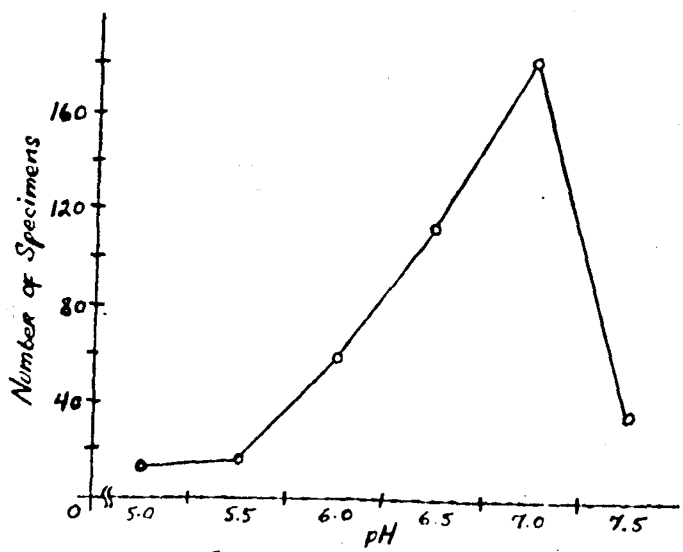
GRAPH 8. STRIATURA MILIUM



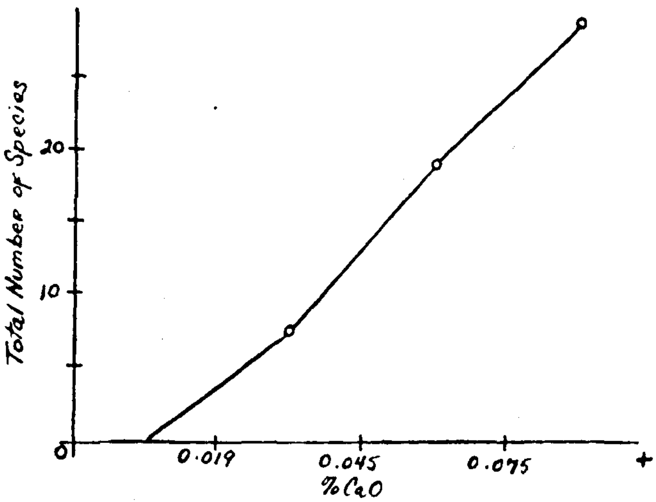
GRAPH 9. STROBILOPS AENEA



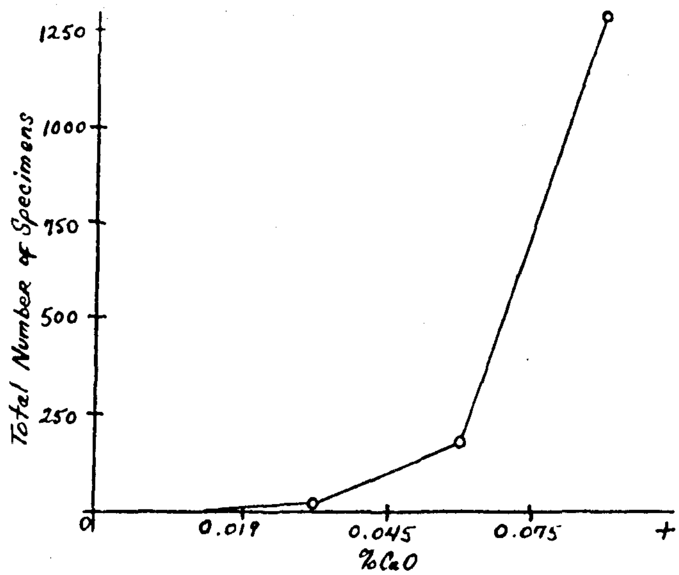
GRAPH 10. TRIODOPSIS TRIDENTATA JUXTIDENS



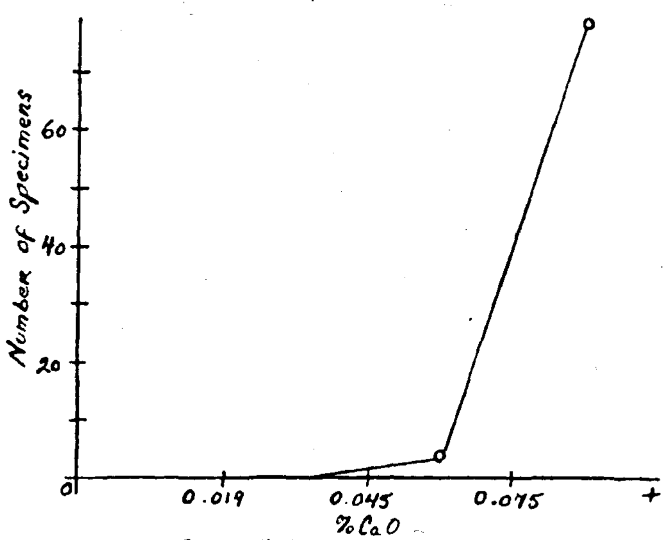
GRAPH 11. ZONITOIDES ARBOREUS



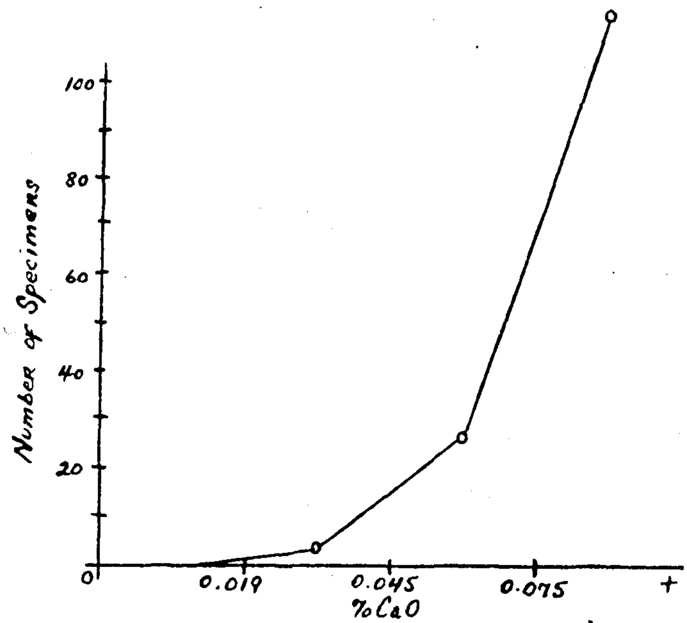
GRAPH 12. TOTAL NUMBER SPECIES



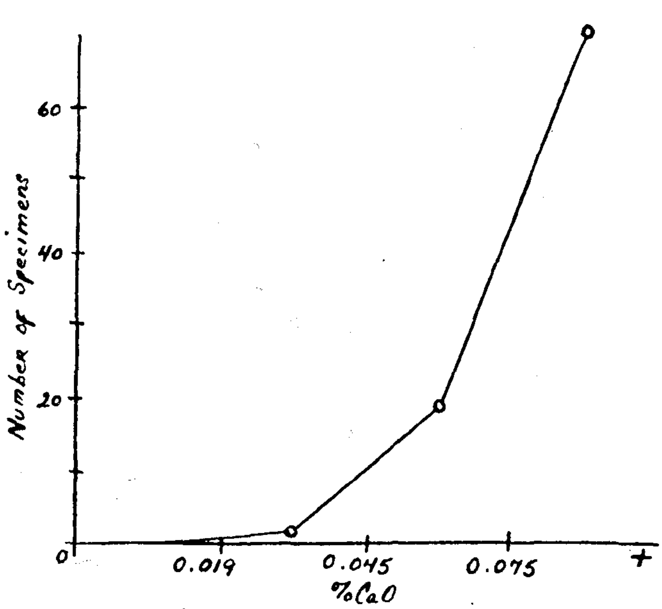
GRAPH 13. TOTAL NUMBER SPECIMENS



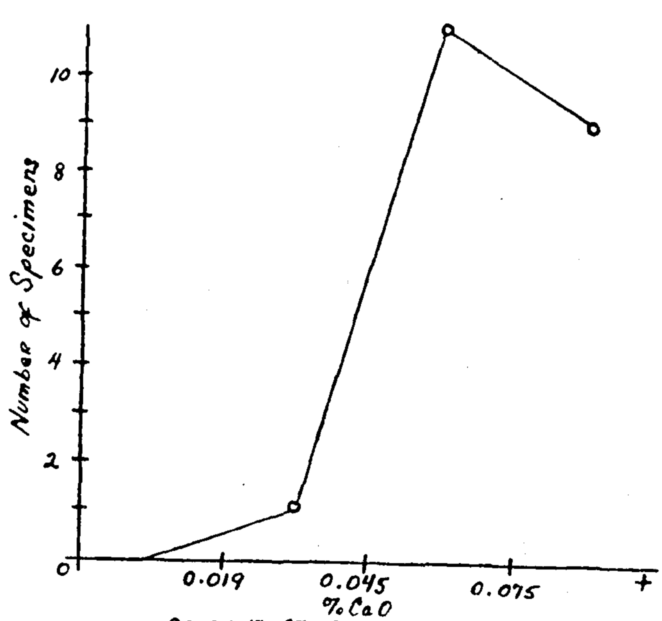
GRAPH 14 HAPLOTREMA CONCAVUM



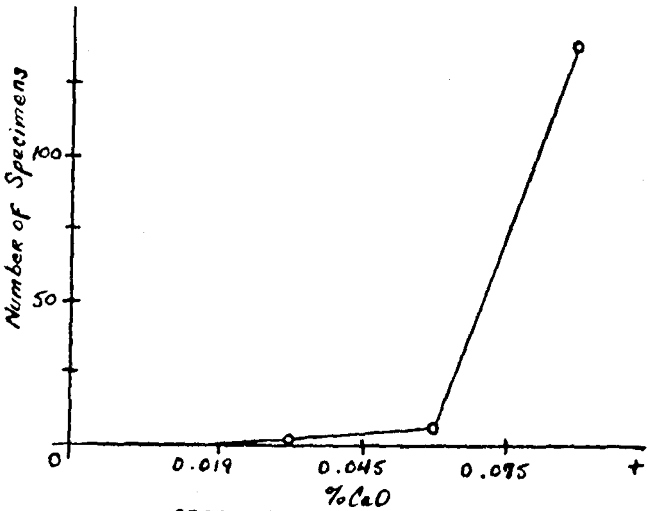
GRAPH 15. HELICODISCUS PARALLELUS



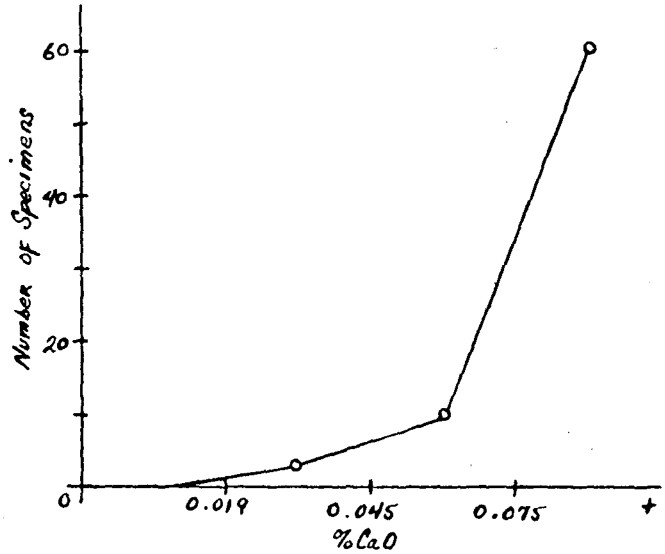
GRAPH 16. RETINELLA INDENTATA



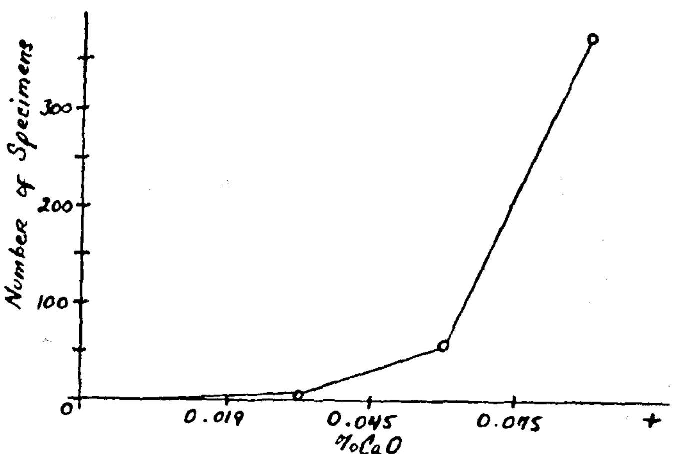
GRAPH 17. STRIATURA MILIUM



GRAPH 18. STROBILOPS AENEA

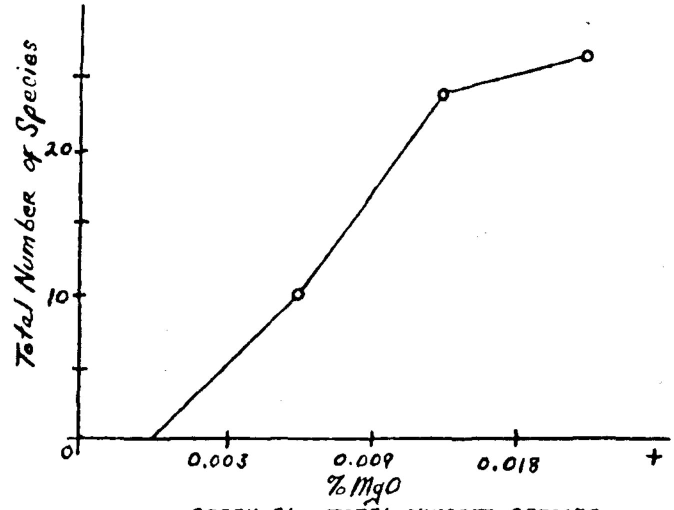


GRAPH 19. TRIODOPSIS TRIDENTATA JUXTIDENS

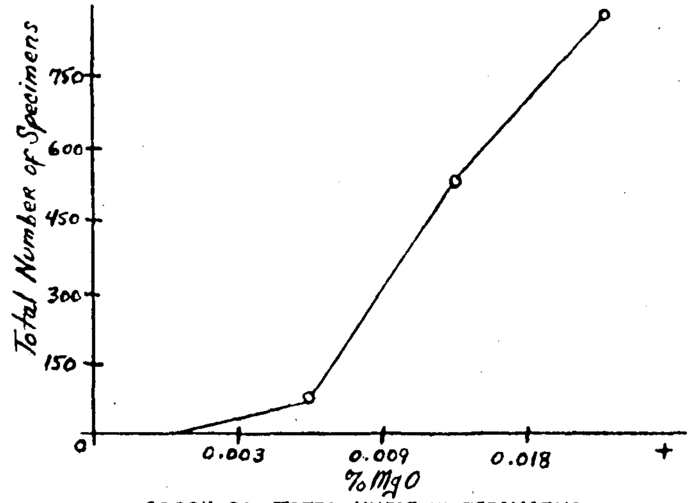


GRAPH 20. ZONITOIDES ARBOREUS

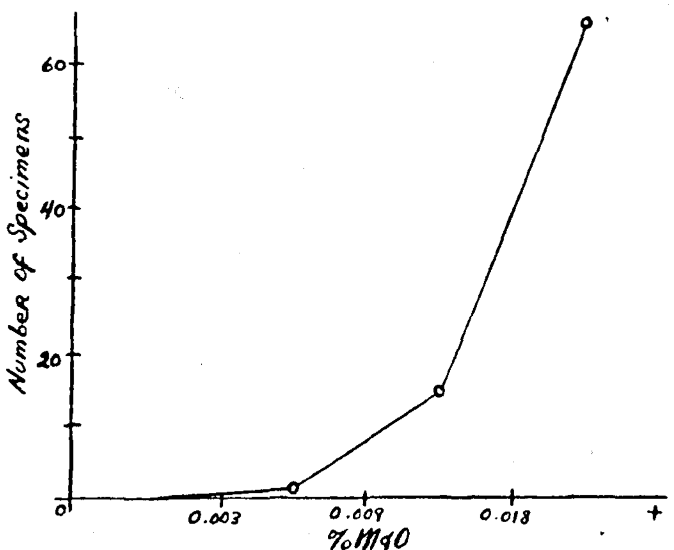
MAGNESIUM



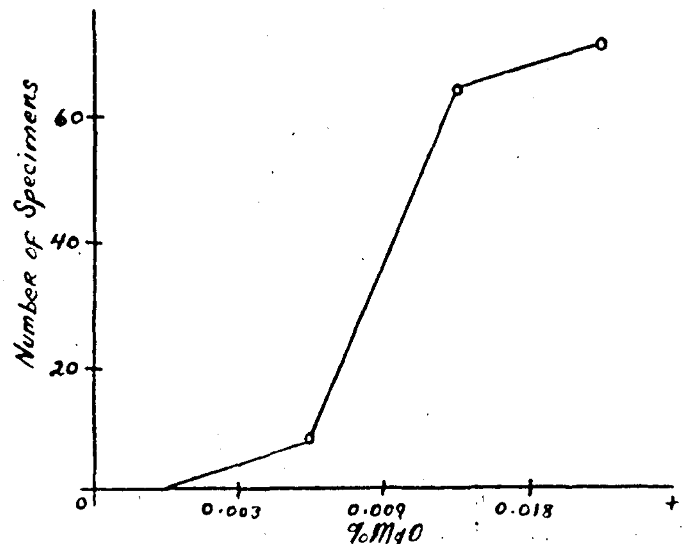
GRAPH 21. TOTAL NUMBER SPECIES



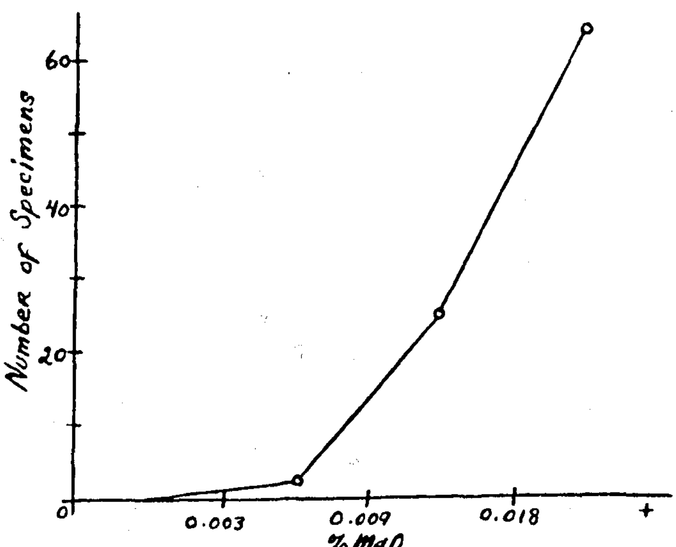
GRAPH 22. TOTAL NUMBER SPECIMENS



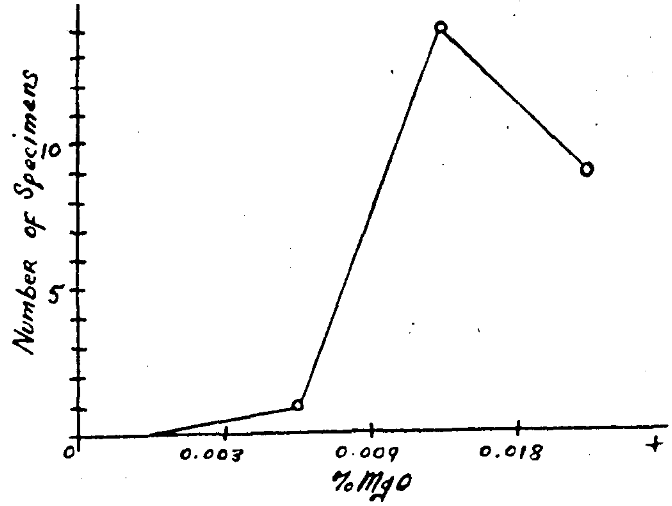
GRAPH 23. HAPLOTREMA CONCAVUM



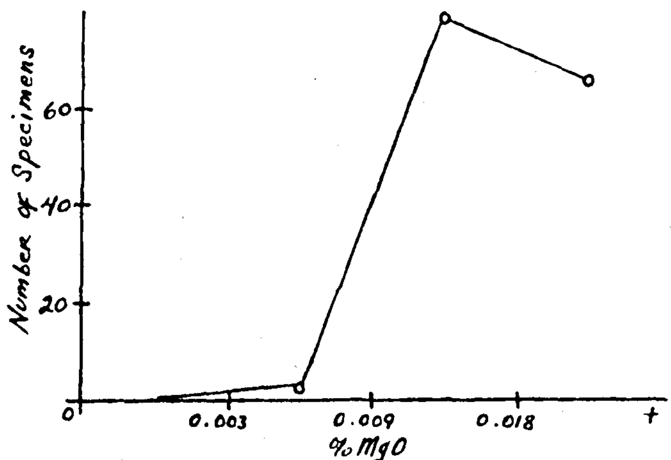
GRAPH 24. HELICODISCUS PARALLELUS



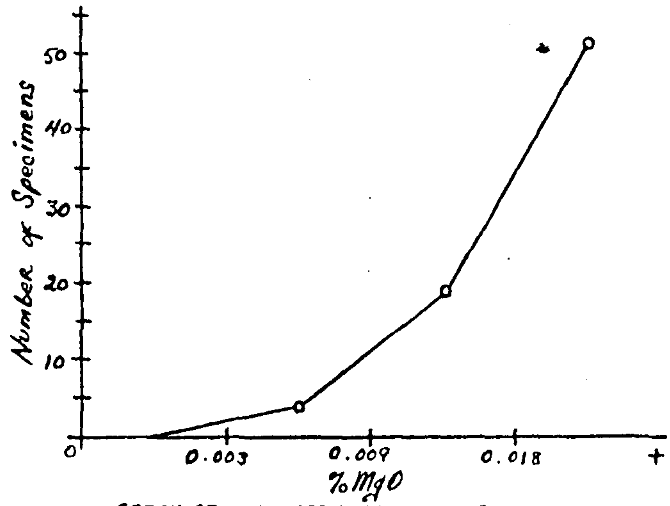
GRAPH 25 RETINELLA INDENTATA



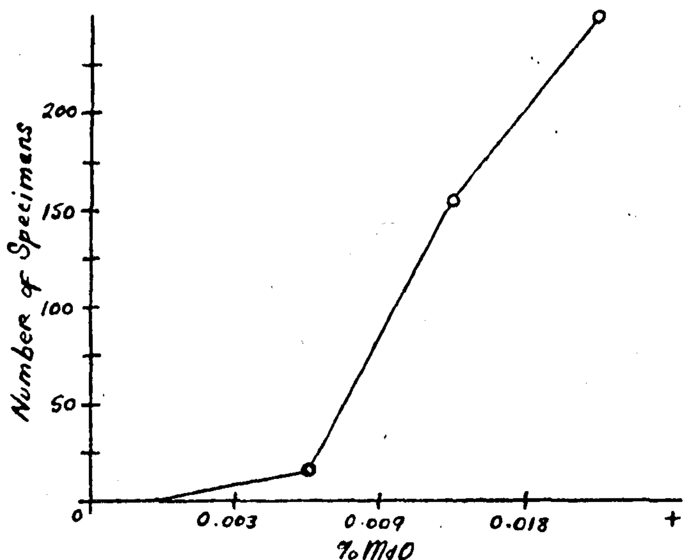
GRAPH 26. STRIATURA MILIUM



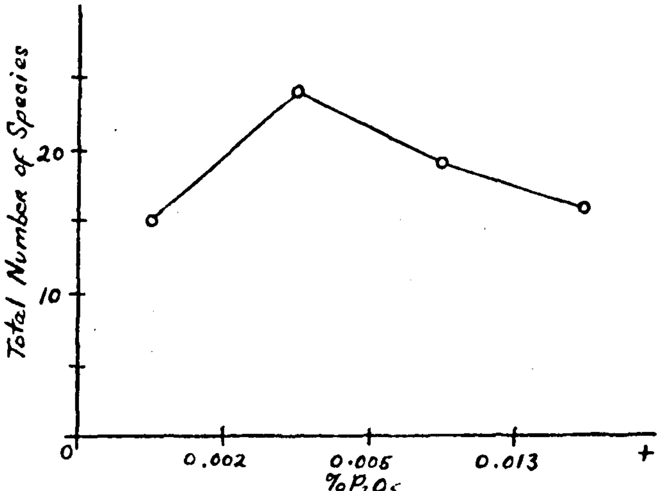
GRAPH 27. STROBILOPS AENEA



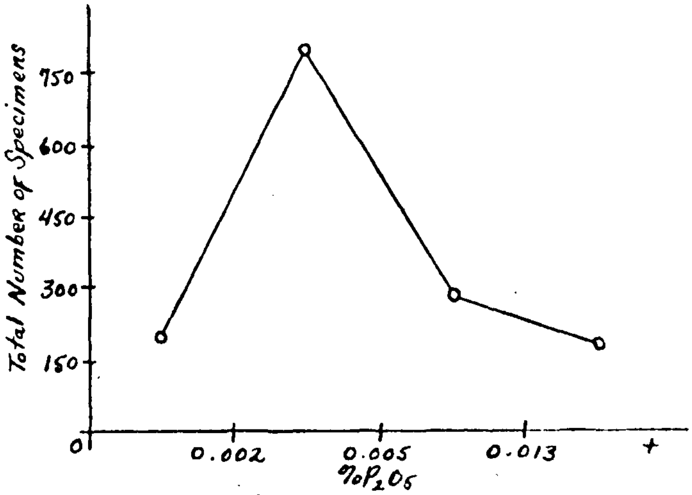
GRAPH 28. TRIODOPSIS TRIDENTATA JUXTIDENS



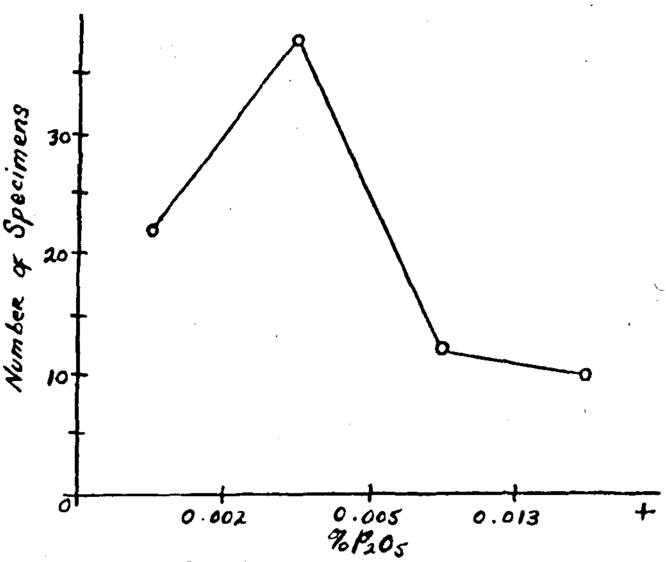
GRAPH 29. ZONITOIDES ARBOREUS



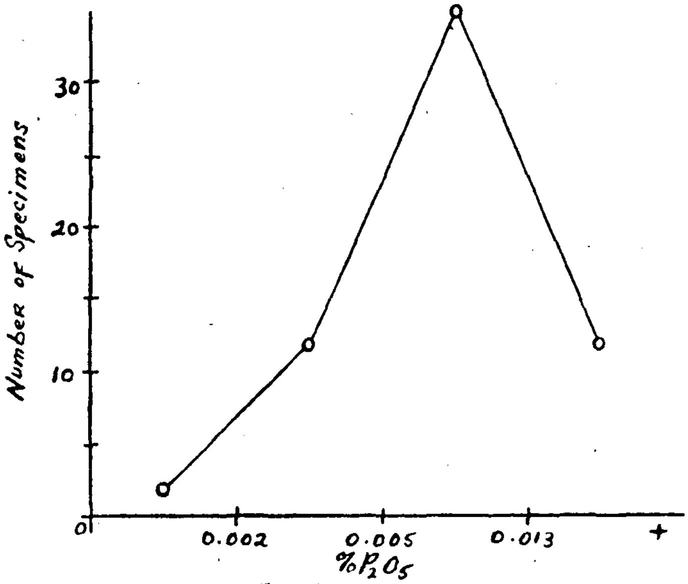
GRAPH 30. TOTAL NUMBER SPECIES



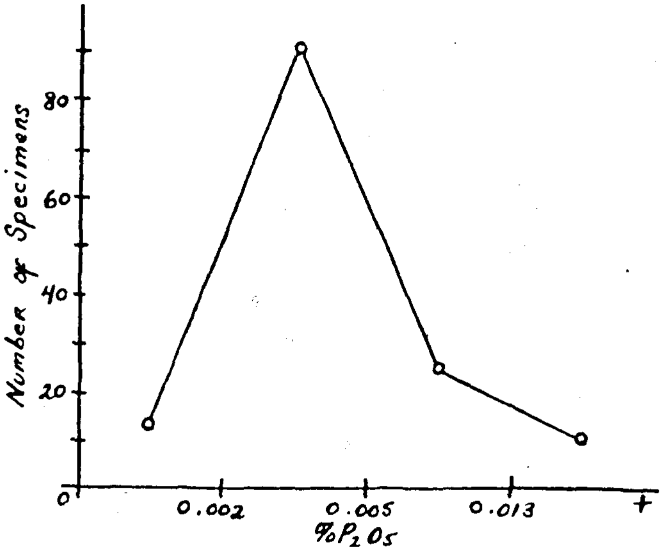
GRAPH 31. TOTAL NUMBER SPECIMENS



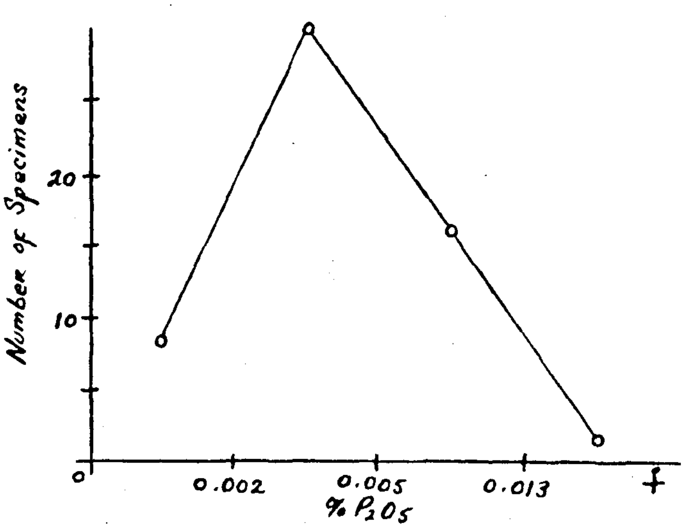
GRAPH 32. HAPLOTREMA CONCAVUM



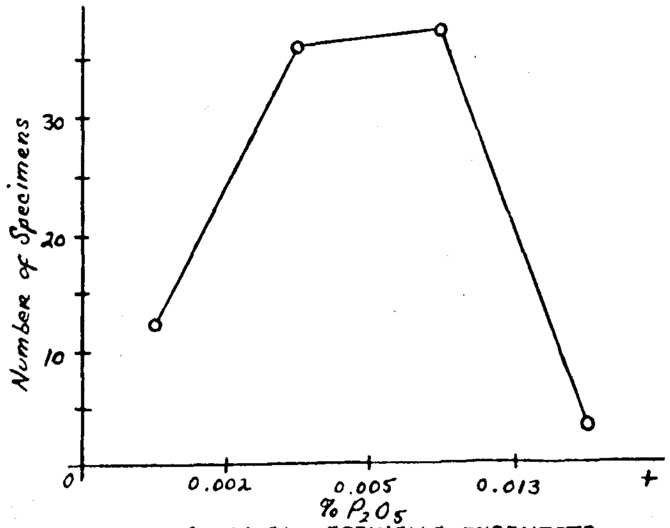
GRAPH 33. HAWAIIA MINUSCULA



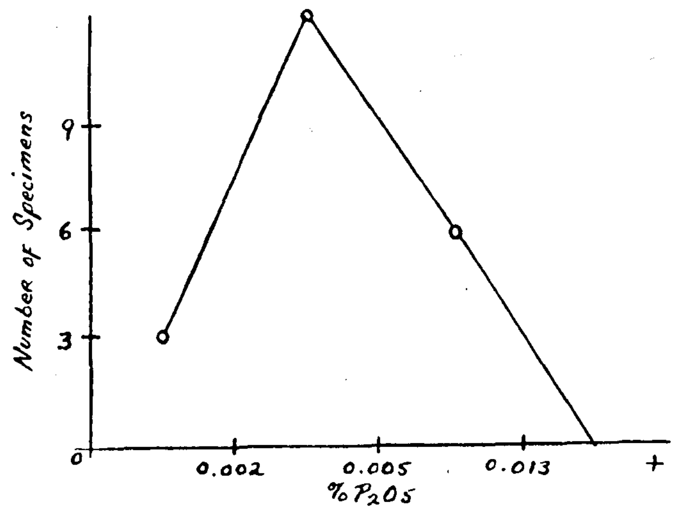
GRAPH 34. HELICODISCUS PARALLELUS



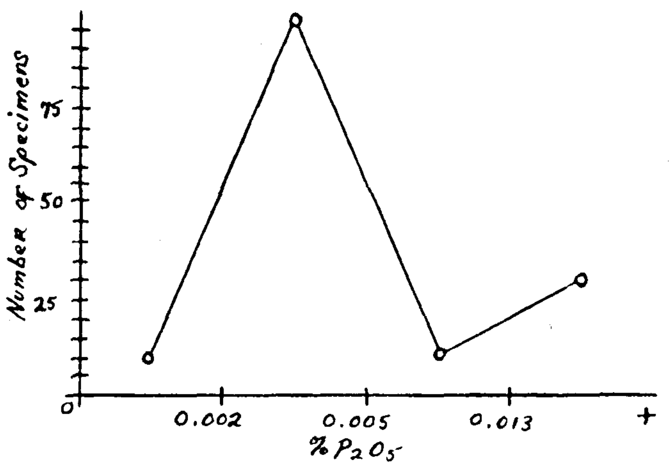
GRAPH 35. RETINELLA BURRINGTONI



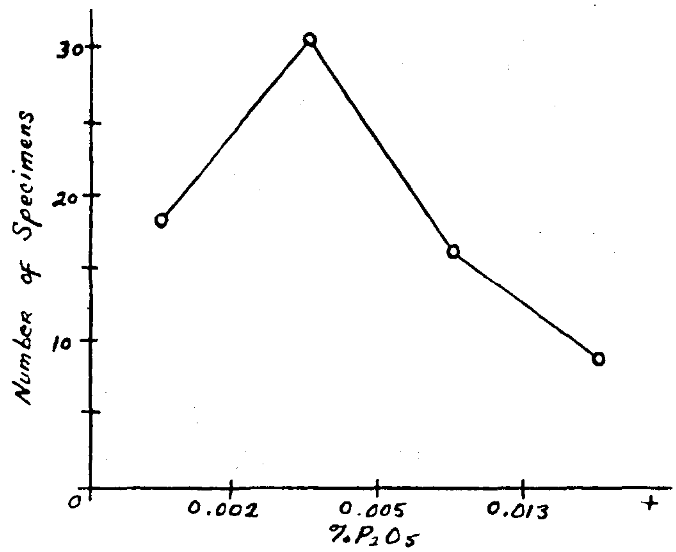
GRAPH 36. RETINELLA INDENTATA



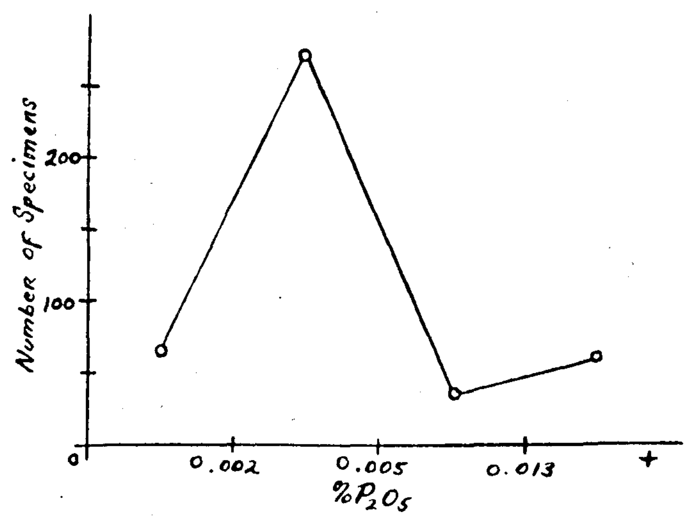
GRAPH 37. STRIATURA MILIUM



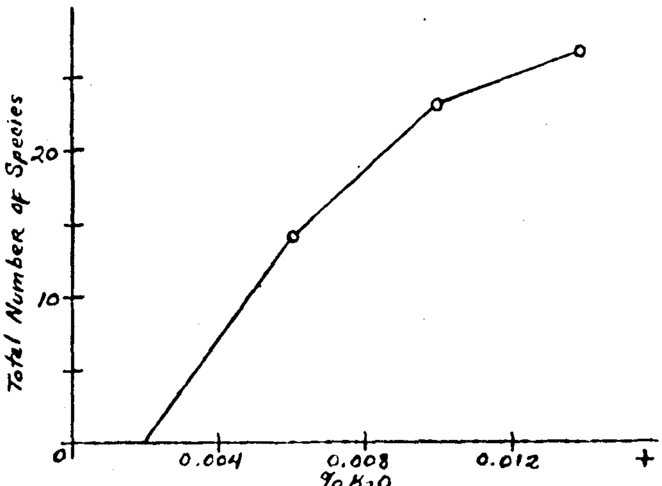
GRAPH 38. STROBILOPS AENEA



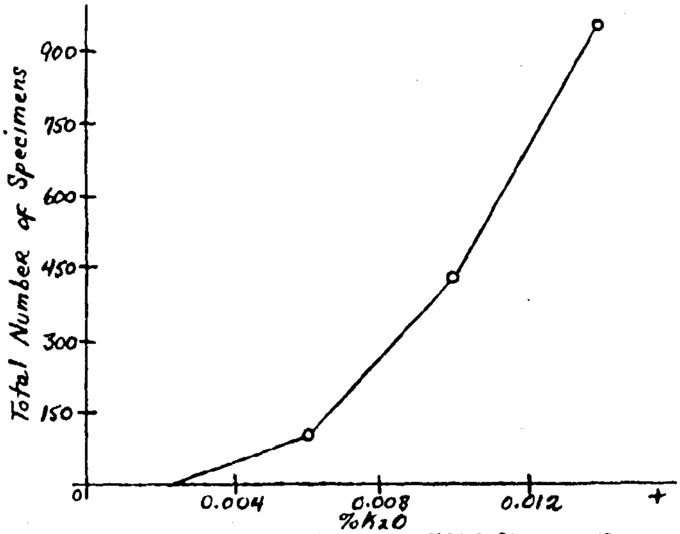
GRAPH 39. TRIODOPSIS TRIDENTATA JUXTIDENS



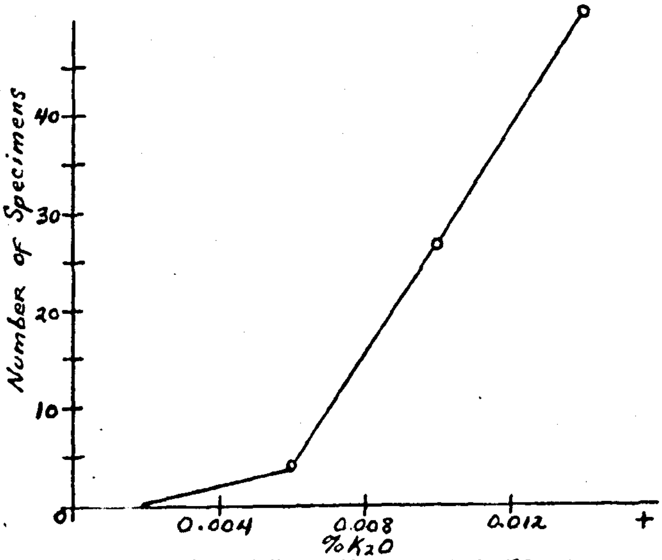
GRAPH 40. ZONITOIDES ARBOREUS



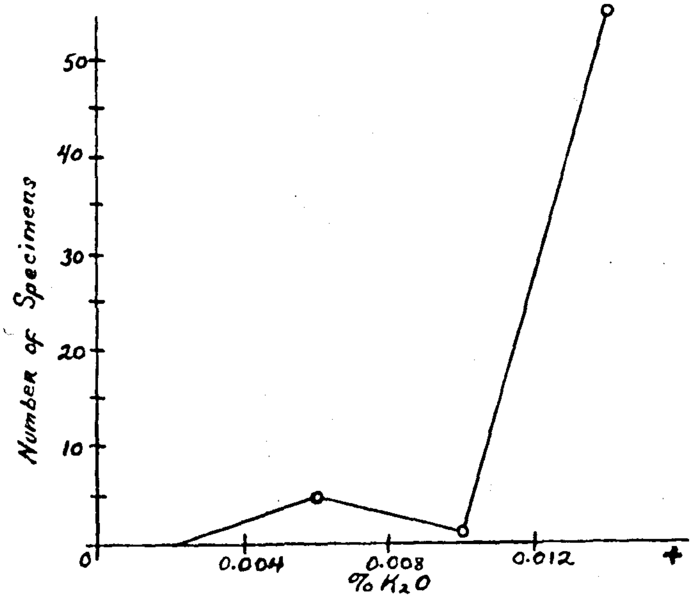
GRAPH 41. TOTAL NUMBER SPECIES



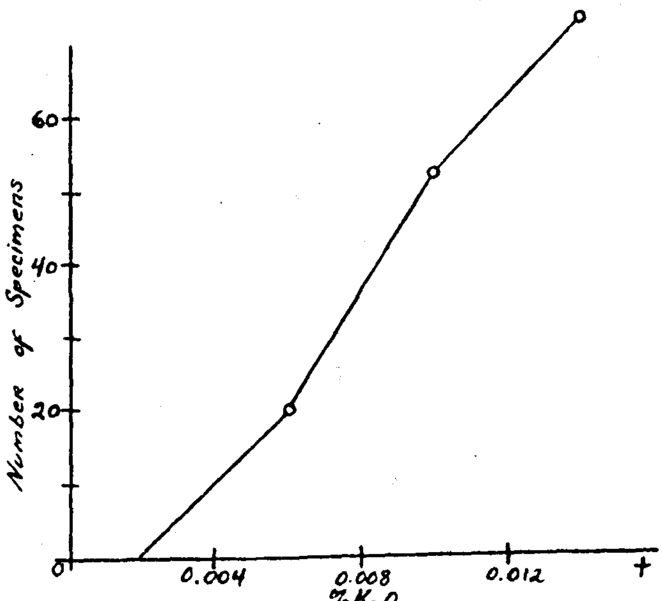
GRAPH 42. TOTAL NUMBER SPECIMENS



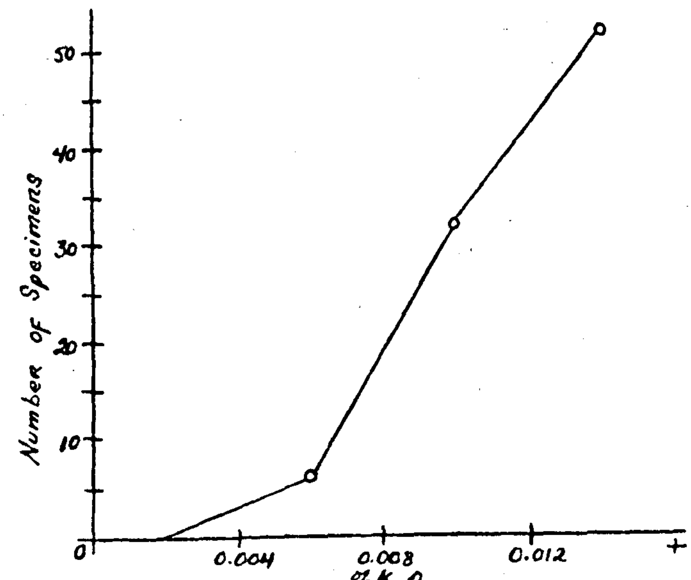
GRAPH 43. HAPLOTREMA CONCAVUM



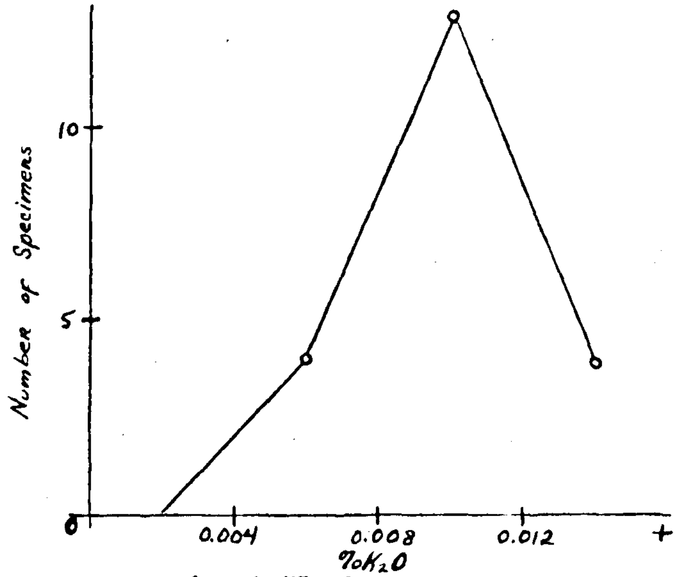
GRAPH 44. HAWAIIA MINUSCULA



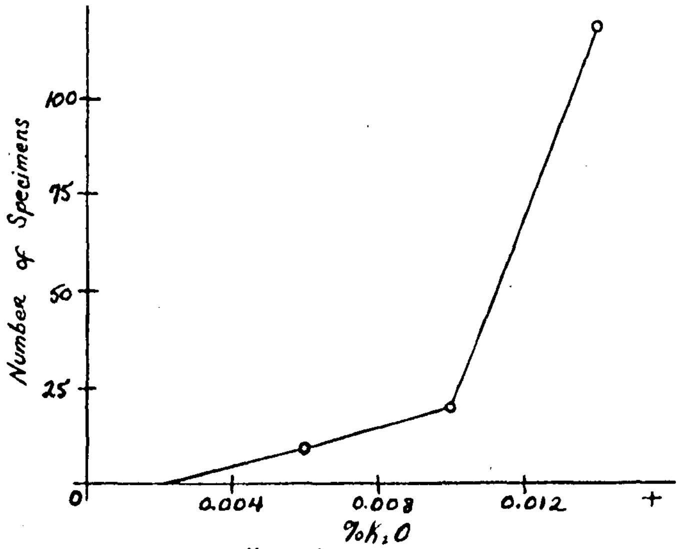
GRAPH 45. HELICODISCUS PARALLELUS



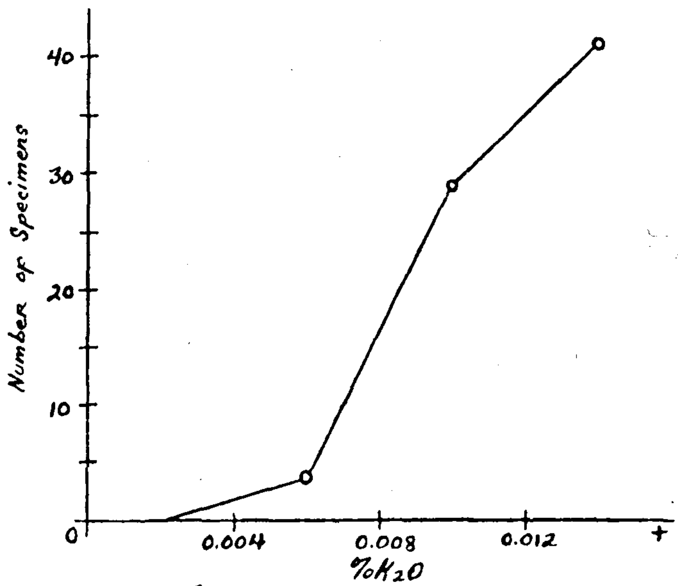
GRAPH 46. RETINELLA INDENTATA



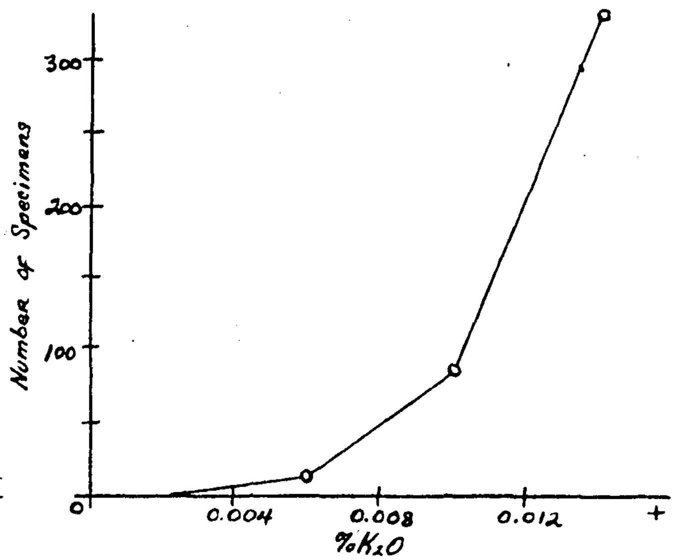
GRAPH 47. STRIATURA MILIUM



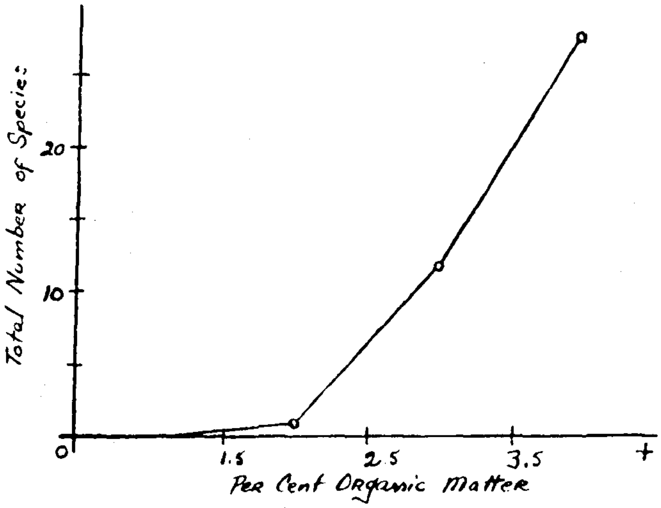
GRAPH 48. STROBILOPS AENEA



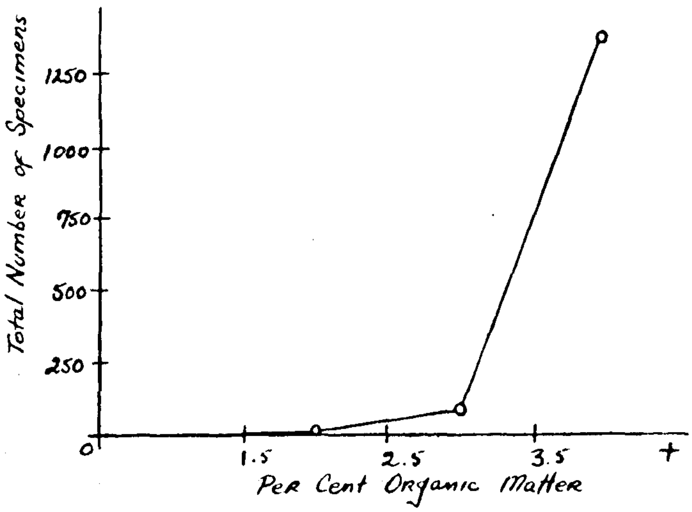
GRAPH 49. TRIODOPSIS TRIDENTATA JUXTIDENS



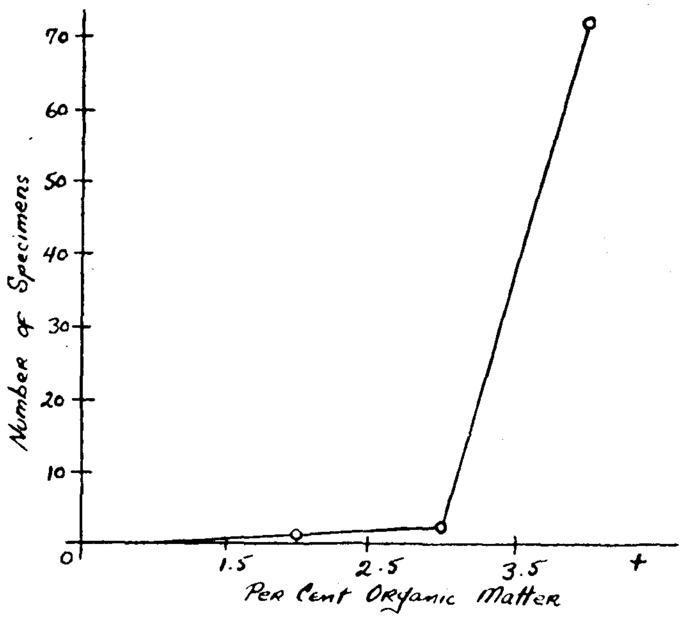
GRAPH 50. ZONITOIDES ARBOREUS



GRAPH 51 TOTAL NUMBER SPECIES



GRAPH 52. TOTAL NUMBER SPECIMENS



GRAPH 53. TRIODOPSIS TRIDENTATA JUXTIDENS

A P P E N D I X M

PLATES AND FIGURES OF LAND SNAIL SPECIMENS

KEY TO PLATES

PLATE I

FIGURE	1.	STROBILOPS AENEA (PILSBRY)
FIGURE	2.	STROBILOPS LABYRINTHICA (SAY)
FIGURE	3.	VALLONIA EXCENTRICA (STERKI)
FIGURE	4.	CARYCHIUM EXIGUUM (SAY)

PLATE II

FIGURE	5.	GASTROCOPTA ARMIFERA (SAY)
FIGURE	6.	GASTROCOPTA CONTRACTA (SAY)
FIGURE	7.	PUPOIDES ALBILABRIS (ADAMS)
FIGURE	8, a.	GASTROCOPTA PENTODON (SAY)
	b	COLUMELLA EDENTULA (DRAPARNAUD)

PLATE III

FIGURE	9.	EUCONULUS CHERSINUS (SAY)
FIGURE	10.	STRIATURA MILIUM (MORSE)
FIGURE	11.	HAWAIIA MINUSCULA (BINNEY)
FIGURE	12.	RETINELLA BURRINGTONI (PILSBRY)

PLATE IV

FIGURE	13.	RETINELLA INDENTATA (SAY)
FIGURE	14.	HELICODISCUS PARALLELUS (SAY)
FIGURE	15, a.	TRIODOPSIS ALBOLABRIS (SAY)
	b.	MESODON THYROIDUS (SAY)
FIGURE	16, a.	TRIODOPSIS FALLAX (SAY)
	b.	TRIODOPSIS TRIDENTATA JUXTIDENS (PILSBRY)

PLATE V

FIGURE	17, a.	MESODON APPRESSUS SCULPTIOR CHADWICK
	b.	TRIODOPSIS HOPETONENSIS (SHUTTLEWORTH)
	c.	ANGUISPIRA ALTERNATA ANGULATA (FERUSSAC)
FIGURE	18, a.	HAPLOTREMA CONCAVUM (SAY)
	b.	VENTRIDENS LIGERA (SAY)
FIGURE	19, a.	SUCCINEA AUREA LEA
	b.	STENOTREMA HIRSUTUM (SAY)
FIGURE	20, a.	CIONELLA LUBRICA MORSEANA DOHERTY
	b.	ZONITOIDES ARBOREUS (SAY)

FIGURE 1 X 10

FIGURE 2 X 15

FIGURE 3 X 13

FIGURE 4 X 13

PLATE I

PLATE II

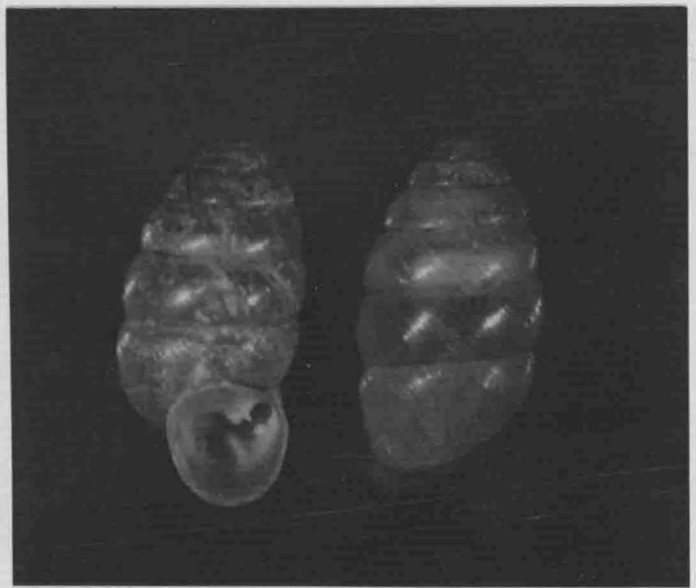


FIGURE 5 X13


FIGURE 6 X13

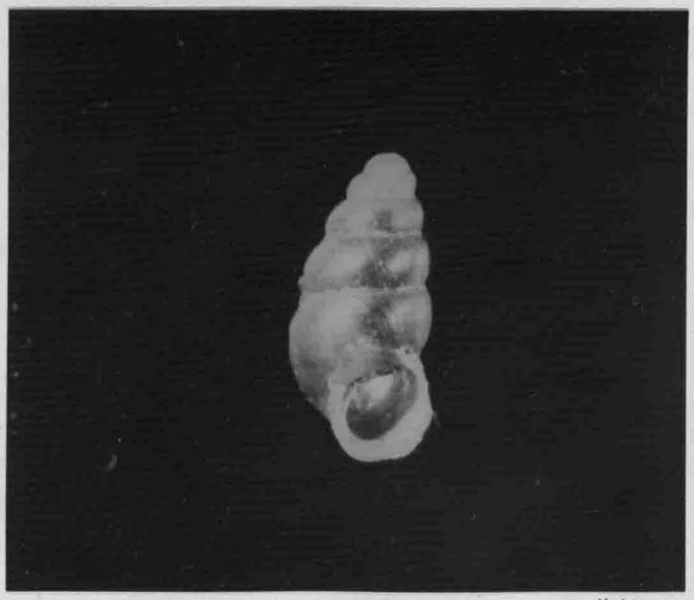


FIGURE 7 X10

FIGURE 8 X20

FIGURE 9 X 13

FIGURE 10 X 20

FIGURE 11 X 13

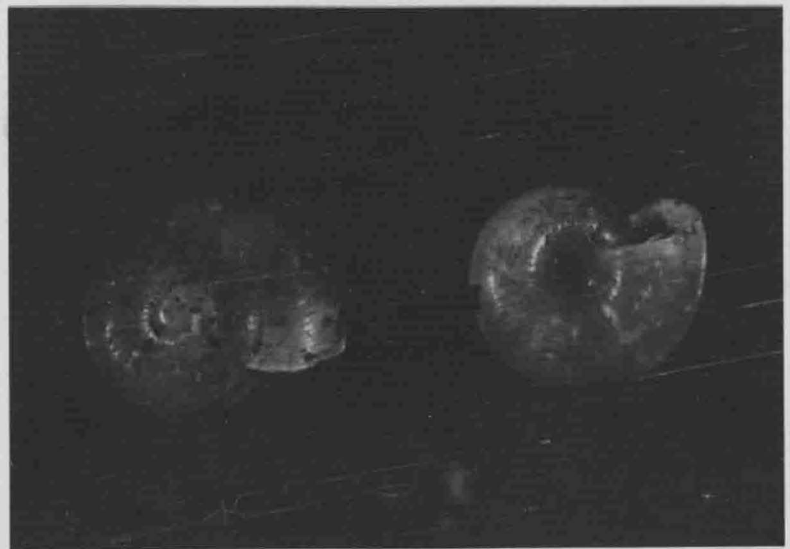


FIGURE 12 X 13

PLATE III

PLATE IV

FIGURE 13 X10

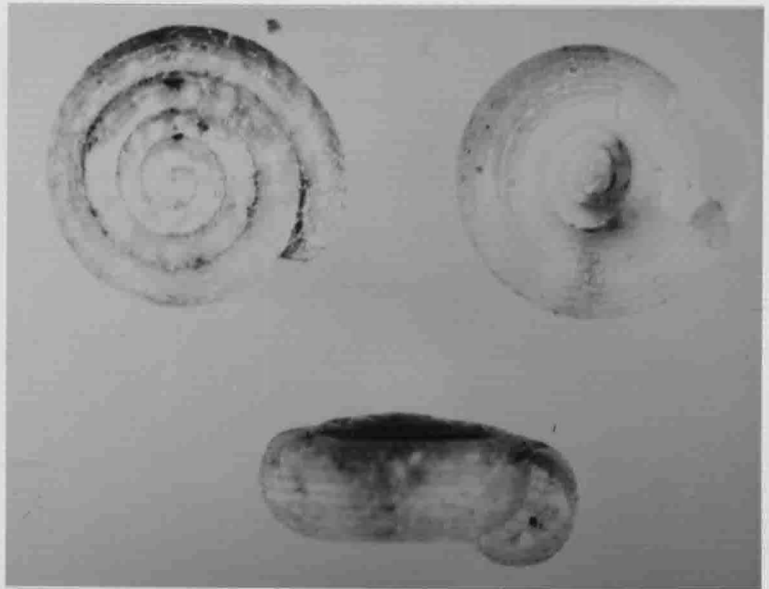


FIGURE 14 X13

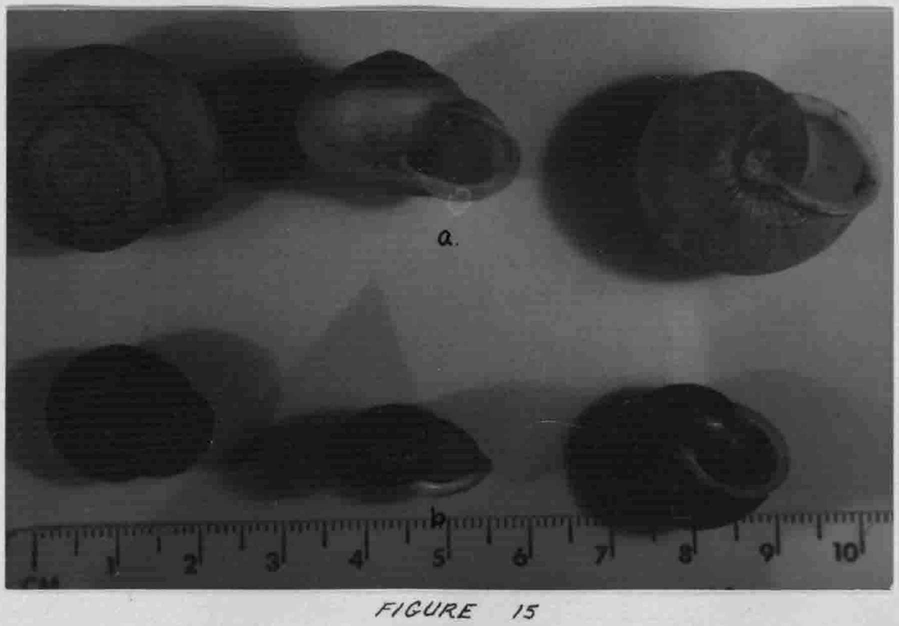


FIGURE 15

FIGURE 16 X1.5

PLATE V

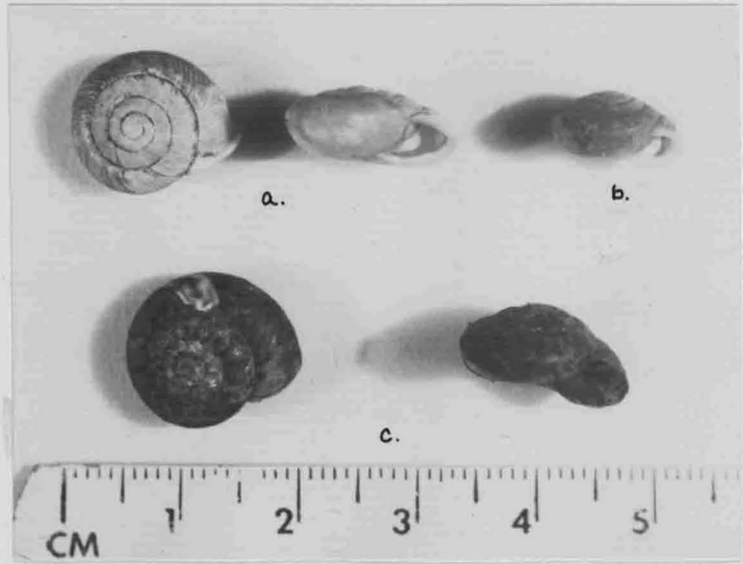


FIGURE 17 X1.5

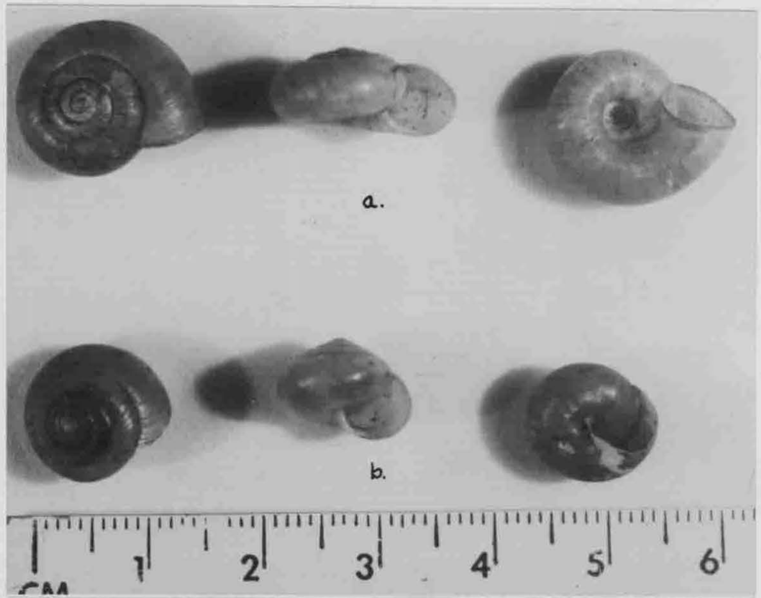


FIGURE 18 X1.5

FIGURE 19 X1.5

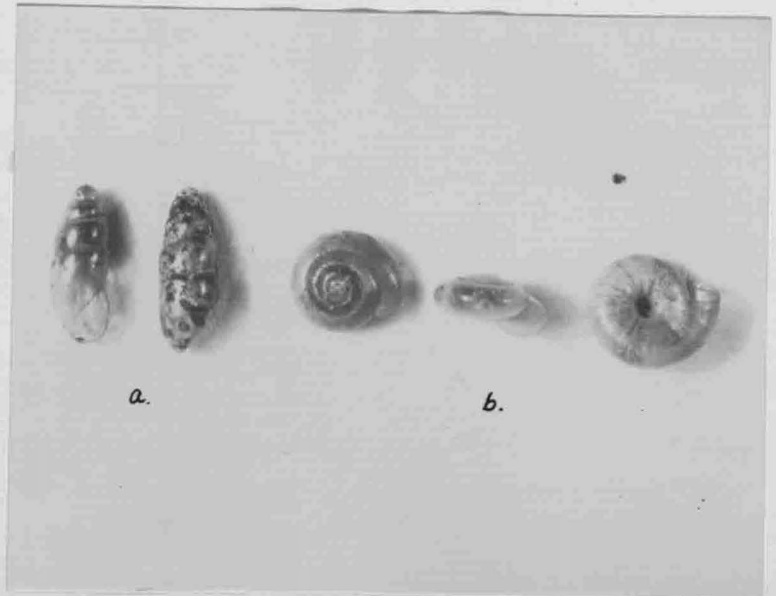


FIGURE 20 X3.

BIOGRAPHICAL SKETCH

John Bayard Burch was born August 12, 1929, in Charlottesville, Virginia. He received his elementary and secondary education in the public schools of Radford, Virginia, graduating from McHarg Elementary School in 1942 and from Radford High School in 1946.

Two years service in the United States Marine Corps delayed his admission to college. In September, 1948, he entered Randolph-Macon College at Ashland, Virginia, and received the degree of Bachelor of Science in June, 1952. He entered the Graduate School of the University of Richmond in September of the same year.

At Randolph-Macon College he served as Student Assistant in Biology, and assisted in Genetics. He served as Graduate Assistant at the University of Richmond in sections of General Biology, Invertebrate Zoology, Comparative Anatomy, and Bacteriology, and held a William's Fellowship in the Graduate School for the term 1953-54.

He is a member of the following honorary and professional societies: Beta Beta Beta, the American Association for the Advancement of Science, the American Malacological Union, the Society of Systematic Zoology, the Ecological Society of America, and the Virginia Academy of Science.

He has received a National Science Foundation Predoctoral Research Award to study at the Mountain Lake Biological Station for the summer session, 1954, and a Teaching Fellowship in the Department of Zoology, University of Michigan, for the 1954-55 session to continue graduate work towards a doctorate degree.